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A STUDY OF

THE FEASIBILITY OF USING ROADSIDE RADIO COMMUNICATIONS

FOR TRAFFIC CONTROL AND DRIVER INFORMATION

A THESIS

Presented to

The Faculty of the Graduate Division

by

Turgut Dervish

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A STUDY OF

THE FEASIBILITY OF USING ROADSIDE RADIO COMMUNICATIONS

FOR TRAFFIC CONTROL AND DRIVER INFORMATION

Approved:

~~Chairman~~

Date approved by Chairman: May 24, 1966

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SUMMARY

The task of communicating with the driver from the roadside is becoming increasingly difficult under increased speeds and massive traffic volumes. A new method of communicating with the driver, involving roadside radio communication, was developed by Delco Radio and tested for the first time in July and August, 1963, on the Kentucky Turnpike. It is a system which provides radio communications from the roadside to the driver and consists of a car mounted receiver and roadside transmitter.

The purpose of this study has been to investigate the feasibility of a system involving roadside radio communication for traffic control and driver information. In making this study, data were used from a study being conducted by the Engineering Experiment Station, Georgia Institute of Technology. The radio communication system used in the study was the system developed by Delco Radio, called Hy-Com.

The experiment designed and conducted for this purpose was concerned with the evaluation of driver behavior at an off-ramp (diverging maneuver) during the nighttime under various test conditions. In this study volunteer participants were randomly assigned to any one of nine test conditions with each test condition providing guidance information about a specific urban freeway exit. The information provided in each test condition varied from very little to a maximum amount and was given through radio communication, highway signing and a combination of both of these modes of communication. While information was being given to

participants in each test condition, data on vehicle operating characteristics were collected at various positions along a section of the freeway selected as the test site. Time-lapse motion photography and the Bureau of Public Roads Traffic Analyzer were used in the collection of the data along the test section prior to the exit ramp. The position of entry of test cars into the deceleration lane was recorded with respect to the beginning of the tapered section of the deceleration lane. These data were then used to determine differences between driver performances along the test section prior to the exit ramp and in the execution of the diverging maneuver from the freeway under the different test conditions.

The results of the analysis of data seemed to indicate that radio communication could be an effective device for traffic control and driver information. Audio messages were found to be as effective as visual messages and test conditions with visual information supplemented by audio messages seemed to provide better driving performance than other test conditions, along the test section and in the execution of the diverging maneuver.

CHAPTER I

INTRODUCTION

Signs, signals and markings have traditionally been the prime means of imparting on-the-spot information to traveling motorists. This task of communicating with the driver in order to inform him of direction, route information and roadway conditions has recently become extremely important under increased speeds and massive traffic volumes.

The problem of keeping a lost or confused driver aware of where he is and what hazards might lie ahead has placed an increasing demand on signs which must compete for attention with other items of interest to the driver including the traffic itself. There have been advances in new sign, signal and marking standards greatly improving the function of these traffic control devices. Typical of some of these advances are the systems presently in use on the New Jersey Turnpike, the Detroit Expressway and the Traffic Pacer System in Michigan.

On the other hand, the number of traffic accidents that occur each year continue to be drastically high in spite of these and other engineering advances. Thus, a more reliable system or a combination of subsystems of communication which will at the right time impart to the driver the information he requires to safely and comfortably reach his destination will also help reduce traffic accidents. Such a system could very well involve radio communications from the roadside to the driver.

Purpose of Study

This study has been the third phase of a research program which was started in January 1963. The purpose of this program was to investigate the feasibility of using roadside radio communications with the driver, evaluate its effectiveness as a traffic control and driver information device and determine the driver's acceptance of this type of communication system.

The experiment designed and conducted for this phase of the program was concerned with the evaluation of driver behavior at an off-ramp during the nighttime driving activity.

The experiment involved nine test conditions with the participation of volunteer test subjects. Each test condition provided guidance information varying from very little information to a maximum amount. The information was given through highway signs, radio communication or a combination of these two modes of communication. While information was being given to test subjects involved in the experiment, data on vehicle operating characteristics were collected at various positions along the freeway and along the deceleration lane. The data collected was then used to determine driver performances along the freeway prior to the exit ramp and in the execution of a diverging maneuver from the freeway.

Previous Work

Prior to this research program, research in roadside radio communication has been very limited. In order to evaluate this method of communication as part of a comprehensive highway communication system, the research in Phase I of this program was conducted in the summer of

1963 and was followed by the research in Phase II in the summer of 1964. These two studies were conducted during the daytime. The following is a summary of these studies. They are described in detail in references (1) and (2) respectively.

The first year of the study program was designed to measure the effectiveness of roadside radio communication as a traffic control and driver information device, to gauge the driver's acceptance of this type of roadside communication, and to obtain enough information to determine a preliminary value of the price the driver is willing to pay for this communication service.

To accomplish stated objectives a section of a rural freeway (Kentucky Turnpike) was selected for study. At a point along the freeway vehicles from the general motoring public were randomly selected and equipped with radio receivers. The drivers were given audio information on accidents, typical highway maintenance activities and route information while traveling through the test section on the freeway. Time-lapse motion photography was used to collect data on traffic flow and the test vehicle drivers were interviewed at the end of the test section.

As a result of the experiment conducted, it was shown that radio communication could be an effective device for controlling speed in hazardous areas. This fact was indicated by significant differences in speeds between test and control vehicles at locations of potential hazard along the test section.

The interview data showed that drivers generally considered radio communication a useful device for providing various types of information in variety of situations. The amount of money that they were willing to pay for a receiver capable of receiving roadside broadcasts indicated driver acceptance of this mode of communication.

The Roadside Radio Communication Experiment performed during the summer of 1964 constituted Phase II of the research program. In this study the feasibility of using roadside radio communication system for traffic control and driver information was investigated on a four-mile section of an urban freeway (Northwest Freeway in Atlanta, Georgia). The primary objective of the study was to evaluate the effectiveness of this system of communication on the decision-making process of the driver as related to his execution of a diverging maneuver from a freeway traffic system. A secondary objective of the study was to evaluate the effectiveness of roadside radio communication as a warning and informational device on a freeway system in an urban environment.

The primary experiment involved a series of individual tests with the participation of volunteer test subjects. Several different test conditions were developed, each with different combinations of audio and visual guidance information provided at a specific freeway exit ramp. While information was being given to test drivers involved in the experiment, traffic data were collected at various locations along the test section. Time-lapse motion photography and the Bureau of Public Roads Traffic Analyzer were used in the collection of data.

The secondary experiment conducted concurrently with the primary, consisted of providing test drivers audio information on accidents, typical highway maintenance activities and route information while traveling through the test section on the freeway.

The results of the study indicated that there were no significant differences between the driving performance of test vehicles, at a point one-half mile in advance of the exit ramp under the different test conditions involved in the experiment.

When the guidance information consisted of both advance and exit information, in general, the manner in which the motorists operated their vehicles did not significantly differ neither in speeds nor rates of deceleration along the deceleration lane and exit ramp.

When the guidance information consisted of the standard advance highway signs only, however, motorists traveled at significantly lower speeds throughout the length of the deceleration area than motorists traveling under conditions of standard advance and exit signing supplemented with advance and exit audio messages.

Roadside radio communication was indicated to be an effective device in warning motorists of potential hazards along the highway as evidenced by significantly different vehicle speeds between test and control drivers during the grass cutting experiment.

Finally, the results of the study indicated that the amount of information given to a driver either by a sign or radio influenced the manner in which the diverging maneuver was made at the off-ramp.

Current Research in Progress

Another study involving roadside induction radio communication for traffic control and driver information is being conducted currently by the California Division of Highways. This study is discussed in more detail in reference (4).

In this study a 700 foot section of a freeway has been selected as test site. The roadside transmitting equipment consists of a tape recorder which feeds a prerecorded message into an audio amplifier. The amplified output is then fed into a loop of wire buried along the roadway, and a magnetic field, varying in accordance with the message, is set up in the vicinity of the loop.

The receiving equipment installed in test vehicles consists of a small magnetic pickup coil in which a varying current is caused to flow by the magnetic field from the roadside loop. This signal is fed into a transistorized amplifier and then to a loudspeaker. The loudspeaker relays the recorded message to the driver. As long as the test vehicle remains within the confines of the wire loop the voice continues to repeat the message. The message fades away only when the car has traveled the 700 foot limit of the system's sphere of influence.

CHAPTER II

COLLECTION OF DATA

Study Area

Several freeways in the Atlanta metropolitian area were evaluated for test sites. The test site finally selected on Interstate 20, east of the center of the city, had several desirable features. This freeway had fairly high-type geometrics, location for cameras and analyzers, power for analyzers, and proximity and convenience to Georgia Tech. An off-ramp within the limits of the test section was undersirable and therefore, would need to be closed to traffic during the experiment. This was a low-volume ramp and with the experiment conducted for two and one-half hours, well past the evening peak hour, it was possible to close the ramp by authority obtained from the City of Atlanta. The location of the study area is shown in Figure 1.

The East freeway was designed in 1957 and is a six-lane highway with three travel lanes in each direction. There are certain geometric features of the facility which are below present day urban freeway design standards. The three twelve foot wide concrete travel lanes provided in each direction on the freeway in the test section are separated by a nine foot wide, raised, turf median as opposed to a minimum desirable width of twenty feet for raised medians. Present standards recommend medians with widths of 20 to 25 feet constructed with mountable curbs and a 3 to 5 foot wide stabilized or surfaced strip along the edges of the median. On the

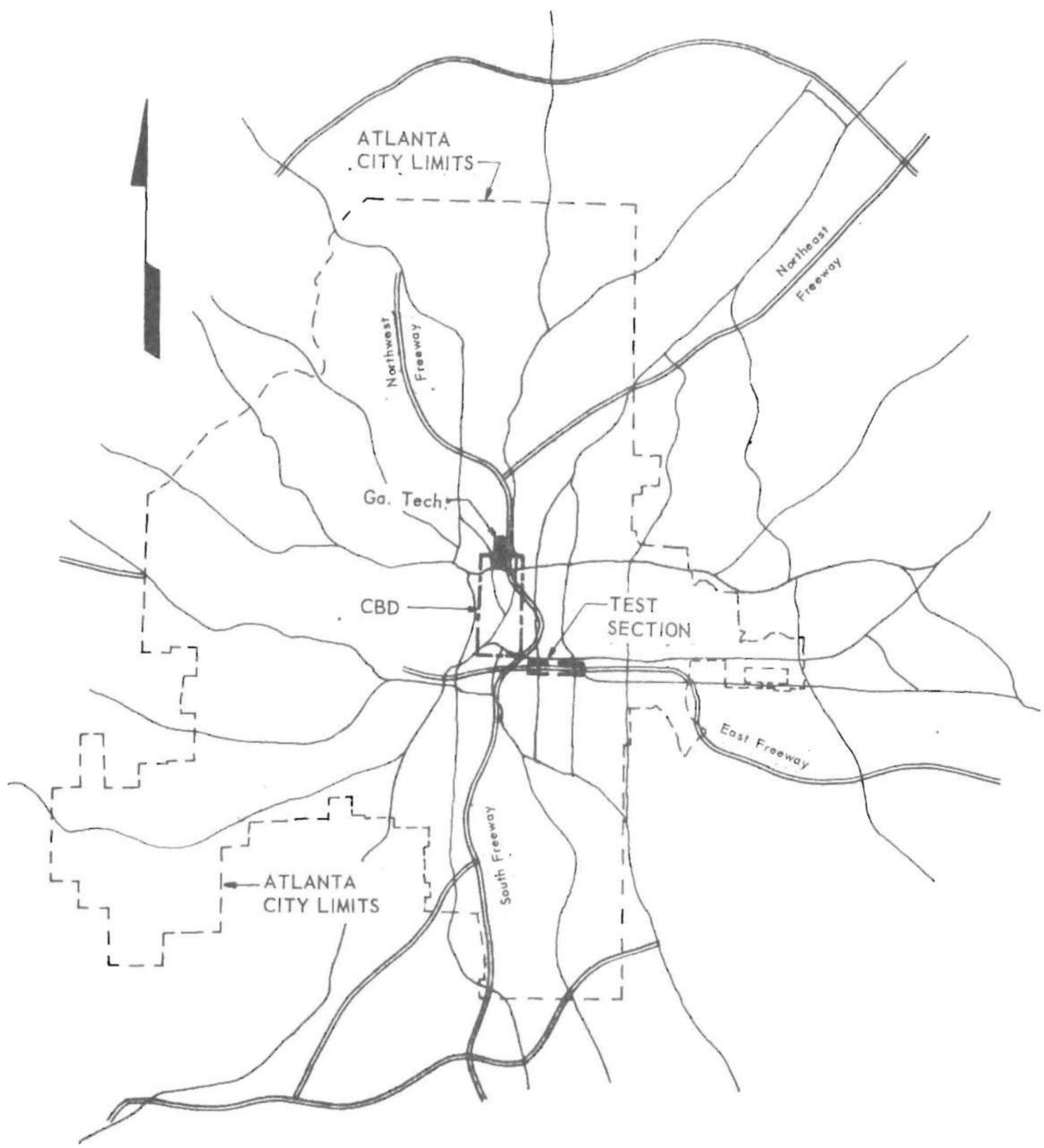

Figure 1. Location of the Study Area.

test section barrier type curbs are used with a two and one-half foot gutter section between the face of the curb and the edge of the travel lane. The freeway had continuous usable shoulders of 10 feet wide as recommended by present design standards.

The exit ramp selected for the purpose of the study was located at the end of the 0.65 mile test section at Hill Street interchange. This exit ramp had a deceleration lane of 600 feet in length, 400 feet being of full 12 foot width. The general configuration of this interchange is shown in Figure 2, and details of the configuration of the deceleration lane and exit ramp are shown in Figure 3.

The traffic approaches the test section with a +3.5 per cent gradient which ends with an 800 foot vertical curve on which four of the speed measurement positions were located. The remaining seven speed positions were on a -0.981 per cent gradient. All measurements were made on the right through lane and traffic volumes recorded during the time of experiment (8:30 p.m. to 11:00 p.m.) showed an average hourly volume of 912 vehicles for all the lanes.

Special Equipment and Instrumentation

The special equipment and instrumentation used in the experiment were for the purpose of communicating with the drivers participating in the experiment and collecting information on vehicle operating characteristics at various locations along the test section.

To communicate with the driver Delco Radio "Hy-Com" and highway signs were used. To collect information on vehicle operating characteristics the Bureau of Public Roads Traffic Analyzer and time-lapse motion

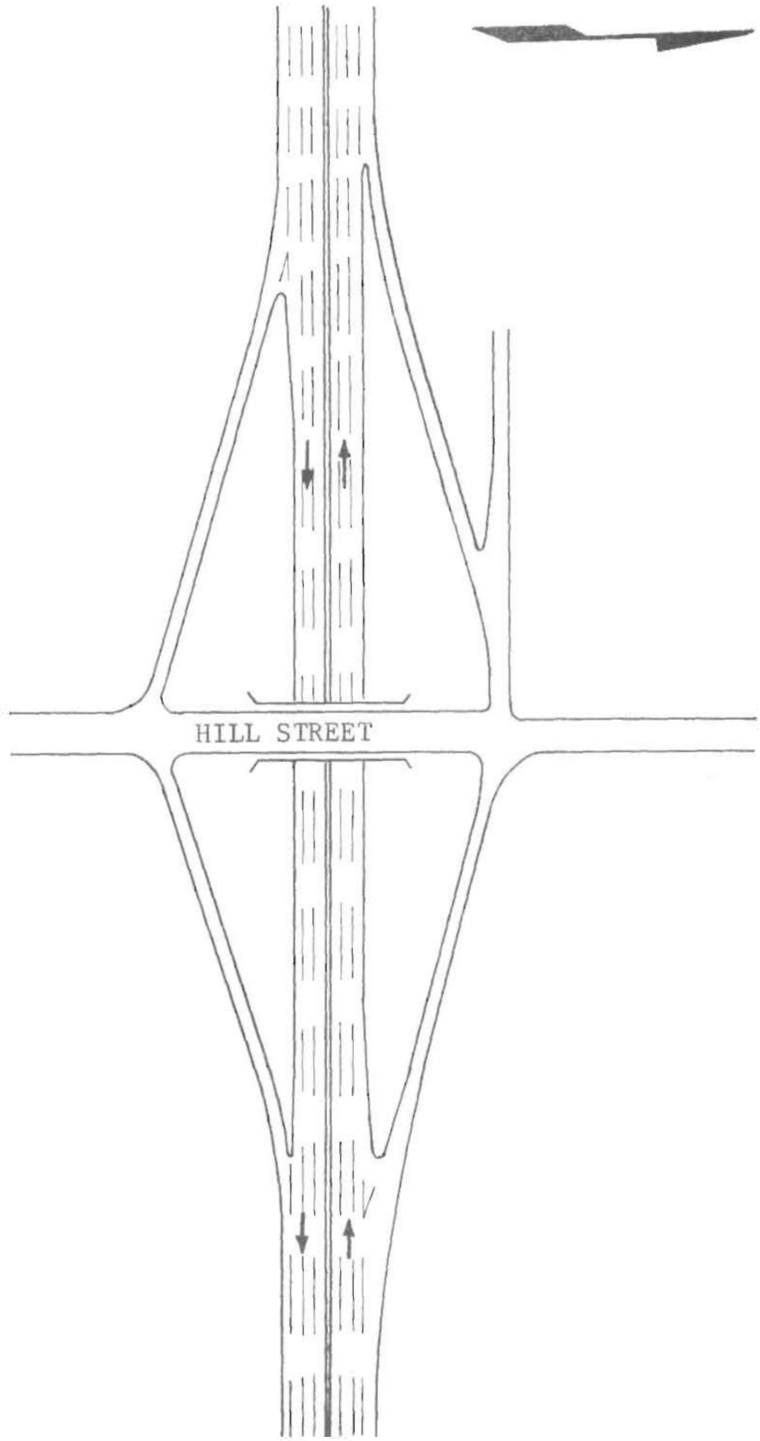

Figure 2. General Configuration of Hill Street Interchange.

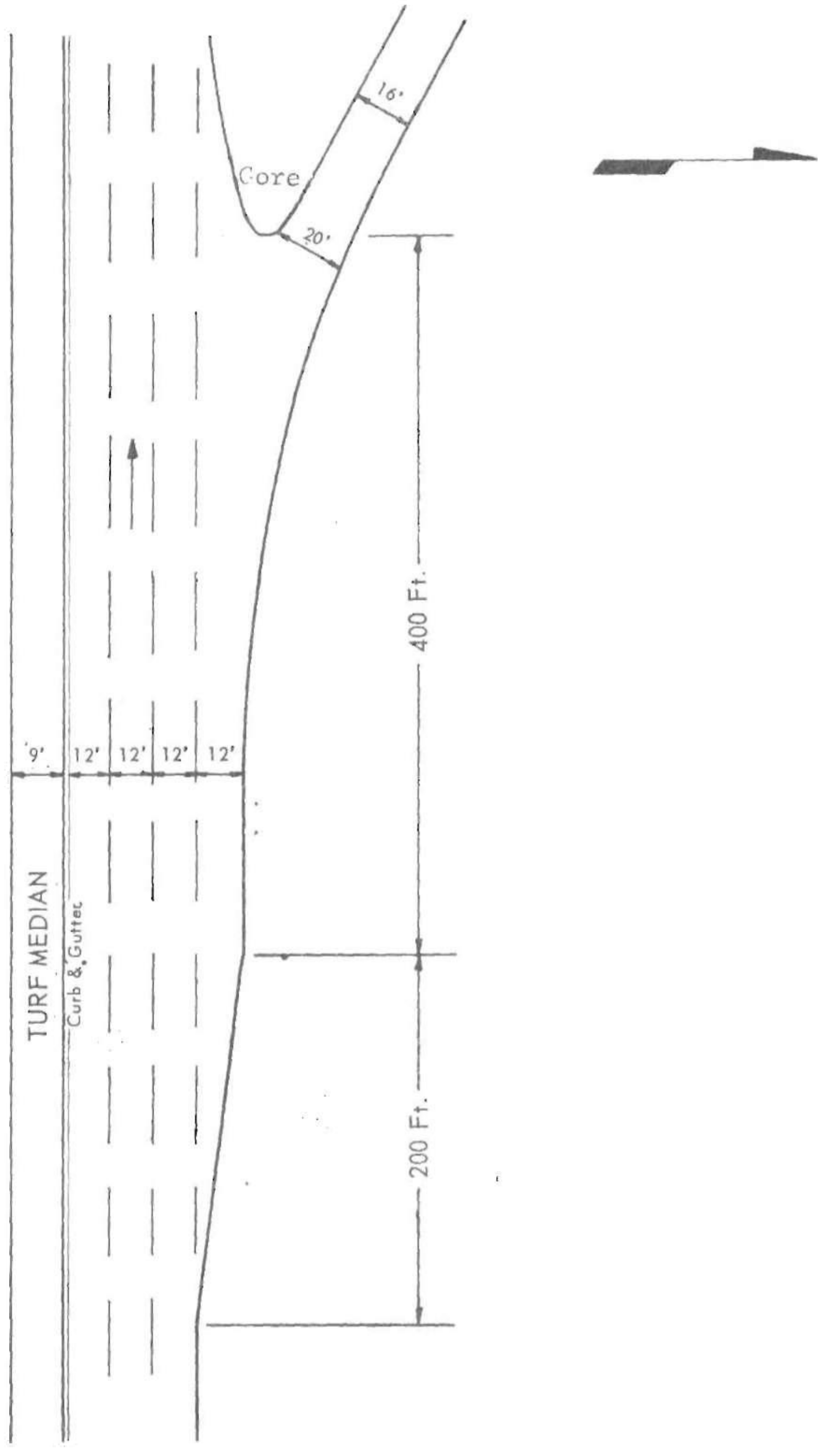

Figure 3. Configuration of the Deceleration Lane and Exit Ramp.

photography were used. These and other equipment used in the experiment are described briefly as follows:

Delco Radio "Hy-Com"

This system of radio communication used in the experiment was developed by Delco Radio, a division of General Motors. It is a system which provides communication from the roadside to the driver and consists of a car mounted receiver and roadside transmitter.

The receiving system consists of a receiver and a speaker. The receiver is encased in a plastic case and has three circular magnets covered with phenolic discs to protect the automobile finish. For most passenger cars a rubber coated safety hook is placed in the crack between the trunk lid and the body of the automobile, and the magnets hold the unit in place on the truck lid of the car. The speaker is cable connected to the receiver and can be mounted on the sunvisor or body trim of the car with a spring clip. Figure 4 shows a receiver mounted on an automobile truck lid.

The transmitting system consists of a transmitter cabinet, message repeater, controller, a trigger and information transmitter, and two loop antennae. The system is a single side band, suppressed one-way communications link and broadcasts signals at 12.1 K.C. Audio messages are recorded on a magnetic drum in the repeater of any duration up to ten seconds, and are automatically repeated. Figure 5 shows the inside view of a transmitter cabinet. No manual manipulation of the equipment is required by the driver. As the receiver of an approaching automobile enters the induction field of the trigger loop antenna

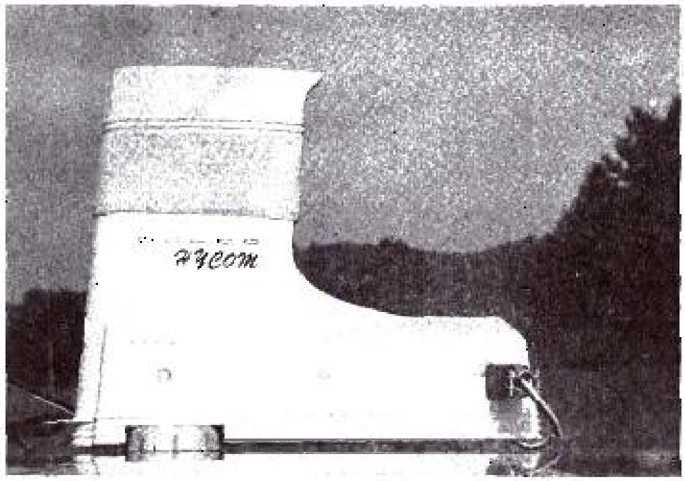

Figure 4. Receiver Mounted on an Automobile Truck Lid.

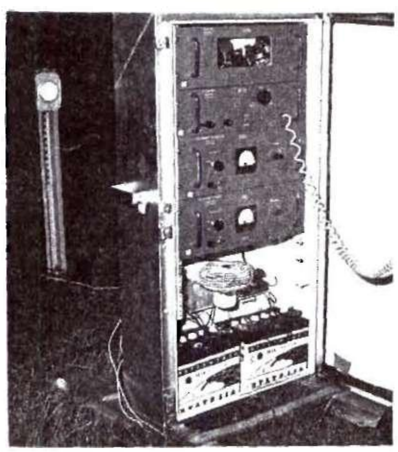

Figure 5. Inside View of a Transmitter Cabinet.

which is positioned on the highway shoulder just prior to the transmitter, a trigger circuit in the receiver is activated which energizes the audio stages of the receiver. A time delay holds the audio section in the "on" position to permit the automobile to reach the information antenna which is positioned just beyond the transmitter. As the receiver enters the field of the information antenna it senses the information signal and provides an audible message to the driver. Figure 6 shows a sketch of a transmitter and two loop antennae positioned along the roadside.

Highway Signs

Highway information signs used in the experiment were constructed of three fourth inch plywood and conformed to freeway signing standards. The advance guidance sign and the exit direction sign were twelve feet by five and a half feet, and the sign at the gore* of the exit ramp was six feet by five feet. These signs consisted of a white legend on a black background as opposed to the standard white legend on a green background. White reflectorized scotchlite tape was used for lettering. Upper case letter height was fifteen inches and lower case letter height was ten inches. Signs used in the experiment can be seen in Figures 7 and 8.

Traffic Analyzer

Two Traffic Analyzers were used in the experiment with each being a mobile unit containing an assembly of equipment which provides automatic digital recording of traffic data at several positions on a highway. One of the analyzers recorded data on adding machine tapes while the other

*See page 11 for location of the gore of the exit ramp.

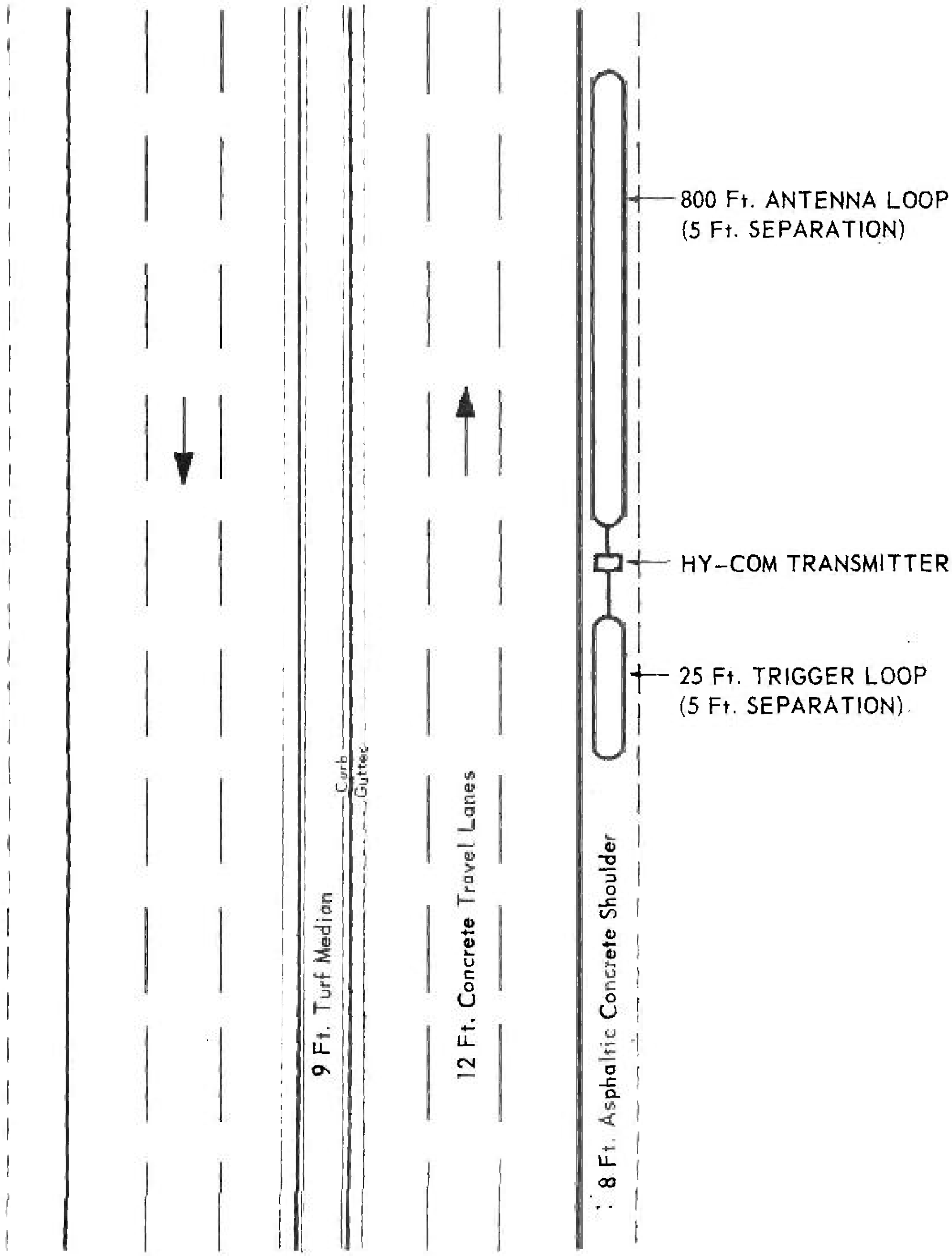

Figure 6. Typical Transmitter Antennae Installation.

Figure 7. Highway Information Signs Used in the Actual Experiment.

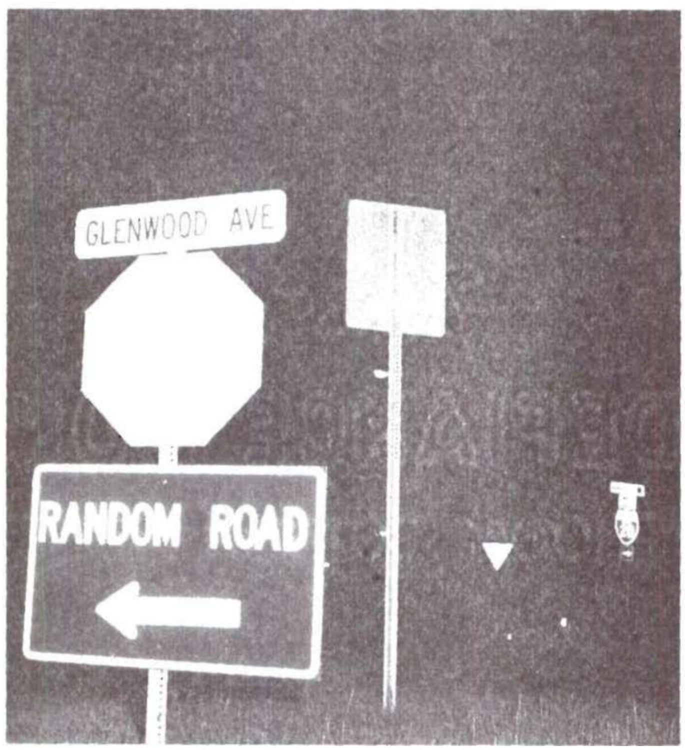

Figure 8. Highway Information Signs Not Used in the Actual Experiment.

recorded data on punch tapes which could be transferred to punch cards for processing. Each unit is essentially equipped with several special recorders, a digital timer to indicate the time for each recording, and a speed timing device.

Speed detectors placed on the highway pavement were pneumatic tubes. As the front wheels of a vehicle passed over the first speed detector tube the speedmeter timer was started. As the front wheels of the same vehicle passed over the second tube of the speed detector, the speedmeter reading in units of one hundredths of a second was entered on the recorder, the reading of the digital timer in ten-thousandths of an hour was transferred to the recorder, and a control signal caused the printing of these data on adding machine or punch tapes. A typical layout of speed detectors is shown in Figure 9. The coding of vehicle types which helped in the tracing of test vehicles through each of the four speed measurement positions was performed manually by depressing the appropriate code digit.

Camera Equipment

The camera equipment for time-lapse motion photography consisted of Bolex 15 mm movie cameras driven by 110-volt AC synchronous motors at a rate of 100 frames per minute. The power for the cameras was provided by employing heavy duty batteries and vibrator type convertors. There were three cameras used in the experiment and each camera exposed three rolls of Eastman 4-X panchromatic negative film each test night. Each roll of film was 100 feet long and provided for a total of forty minutes of filming time. The time interval between each frame was six tenths of one second. All of the cameras were

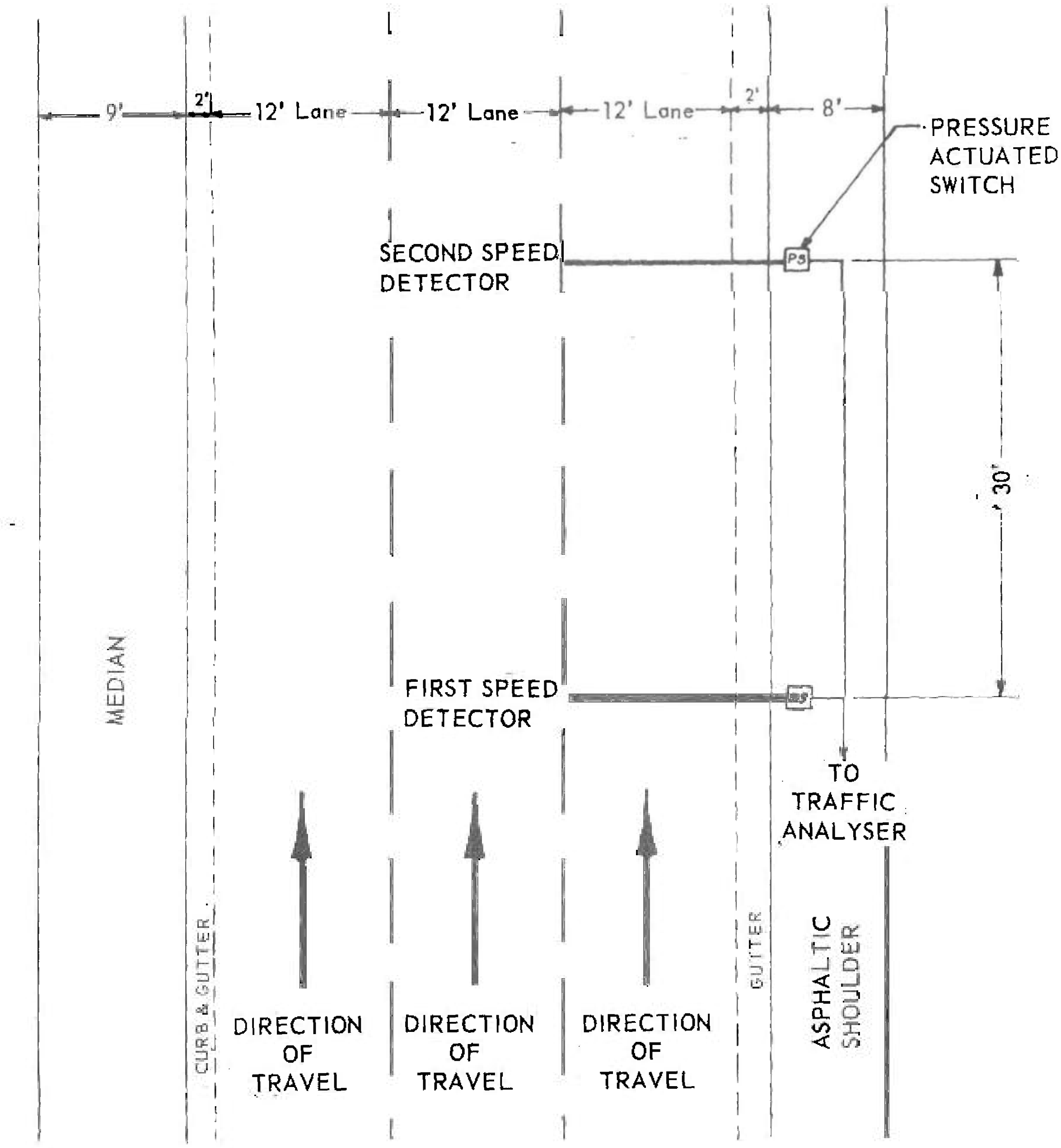

Figure 9. Typical Layout of Speed Detectors.

started at the same time and there were two intervals of ten minutes each for reloading cameras.

At camera observation locations, a grid system was painted on the edges of the highway pavement perpendicular to the center line of the freeway. The grid system extended for a distance of 240 feet at 40 feet intervals at each camera location. Figure 10 shows a typical camera location and grid layout.

Project Control Equipment

To provide a good coordination and efficiency in the performance of the experiment, the staging area, traffic analyzers, the camera positions and any mobile patrol units were linked together with several Citizen Band and Ultra High Frequency radio units.

Design of Experimental Conditions

Test Subjects

Pre-selected volunteer participants from local business offices, institutions, service club organizations, Georgia Tech students and staff were used as test subjects. The test subjects were randomly assigned to one of the nine test conditions employed in the experiment and the order of running these tests was randomized. Each test group was requested to travel over the test section only once, traveling in the right through lane. In the event a slower vehicle was traveling ahead of them, the participants were asked to pass the vehicle and return to the right through lane. It was necessary to close an entrance ramp in the test section in order to avoid the interference of cars entering the freeway with the test cars traveling along the test section. The location of this entrance is shown in Figure 12 (page 28). In order to familiarize the

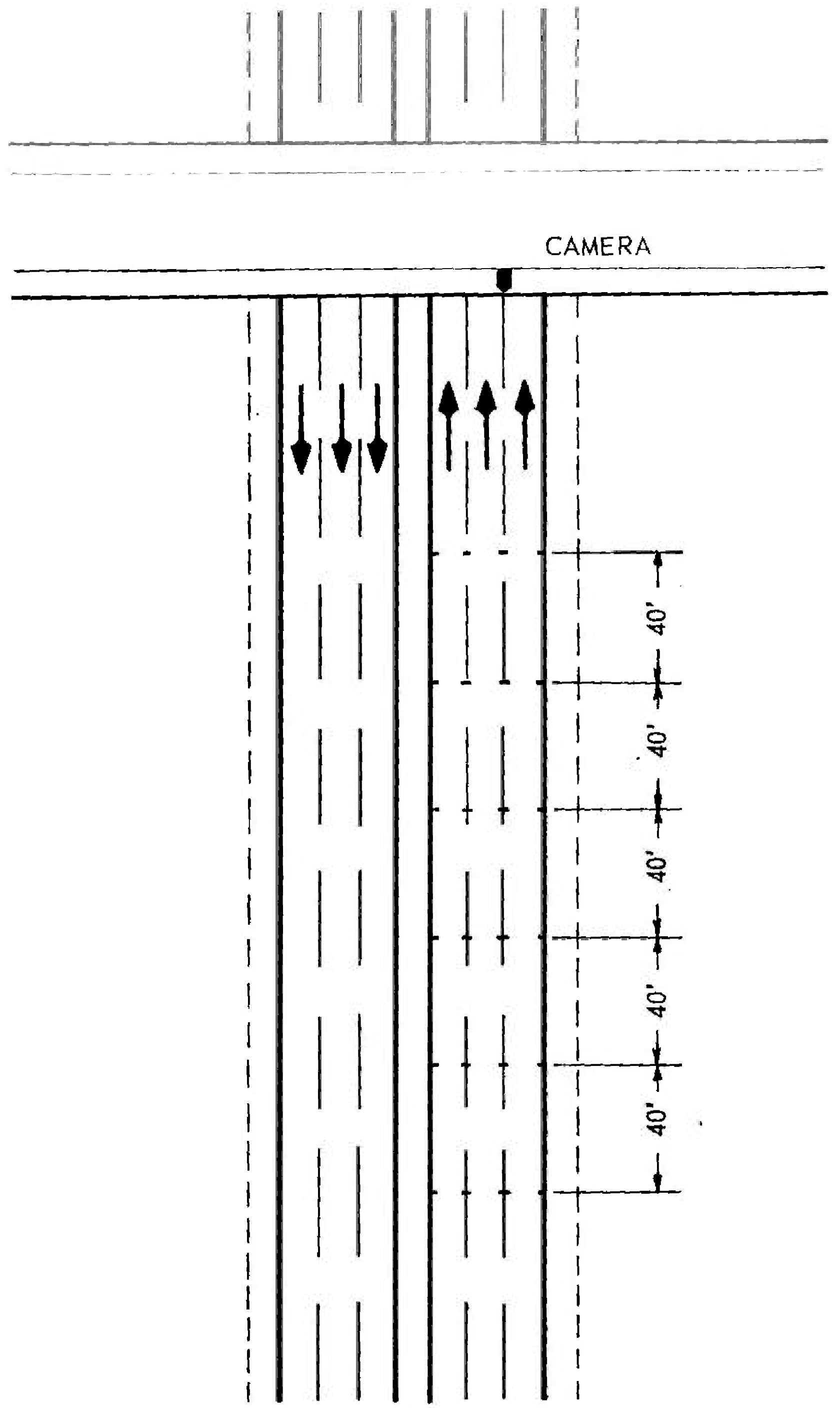

Figure 10. Typical Camera Location and Grid Layout.

test subjects with the operations and characteristics of the radio equipment a briefing session was held prior to the actual running of the experiment. Information given to test subjects may be seen in Appendix A.

Test Conditions

The experiment consisted of nine separate test conditions whereby various combinations of audio and visual information were provided for test drivers in making an exit maneuver from the freeway. The test conditions employed in the experiment are listed in Table 1. In this tabulation visual information refers to information given by highway signing and audio information refers to information given by roadside radio communication. The advance information was provided at a distance of approximately one half mile in advance of the exit ramp, and the exit information near the beginning of the tapered section of the deceleration lane and at the gore of the exit ramp.

Although test subjects participating in the control Group (A_0V_0) were given a radio receiver and speaker, they received no information along the test section except the exit sign at the gore of the exit ramp.

Performance of Experiment

The experiment was performed in nighttime traffic situation from 8:30 p.m. to 11:00 p.m. during the period from July 19 to August 3, 1965. One test condition was studied each night. In the event of wet pavement or other difficulties a test condition was rescheduled for a later date after all other test conditions were run.

The participants arrived at the staging area where project personnel installed Hy-Com receivers and speakers on the vehicles of test subjects.

Table 1. Test Conditions Employed in the Experiment

Test Condition	Explanation of Test Condition
A_0V_0 (Control Group)	Minimum Possible Information (An Exit Sign at the Gore of the Exit Ramp)
A_0V_1	No Audio Information Visual Advance Information
A_1V_0	Audio Advance Information No Visual Information
A_1V_1	Audio Advance Information Visual Advance Information
A_0V_2	No Audio Information Visual Advance and Exit Information
A_2V_0	Audio Advance and Exit Information No Visual Information
A_1V_2	Audio Advance Information Visual Advance and Exit Information
A_2V_1	Audio Advance and Exit Information Visual Advance Information
A_2V_2	Audio Advance and Exit Information Visual Advance and Exit Information

A light bulb lit by the power supply of the car battery was attached to the grill off-centered to the lower right front of each car. Bumper stickers were also placed on the rear bumper. The light bulb and the stickers helped identify cars during data recording as well as during the film analysis process.

A transmitter (No. 1) which was not included in the experiment was located at the staging area to provide a final test for adequacy of performance of the receiver and speaker after their installation, and to help the driver become familiar with the sound of the radio instructions. Driving instructions and directions for travel over the test section were briefly repeated for each driver prior to this departure from the staging area. Then the test driver proceeded along a designated route to the test section and exited at a designated exit ramp. The freeway exit ramp selected for the purpose of the experiment was renamed "Random Road" in order to negate as much as possible the test subjects' specific advance knowledge regarding the exact location of the exit ramp.

Between the staging area and "Random Road" test drivers were given audio, visual, a combination of audio and visual, or no information according to the test schedule employed for each night. In the event they could not find "Random Road" they were asked to return to the staging area. A sketch showing the location of the staging area, test route, test section and transmitters are shown in Figure 11.

Two other transmitters (No. 2 and No. 3) which were not included in the actual experiment were located between the staging area and the test section. These transmitters broadcast information concerning the test route and lane usage respectively.

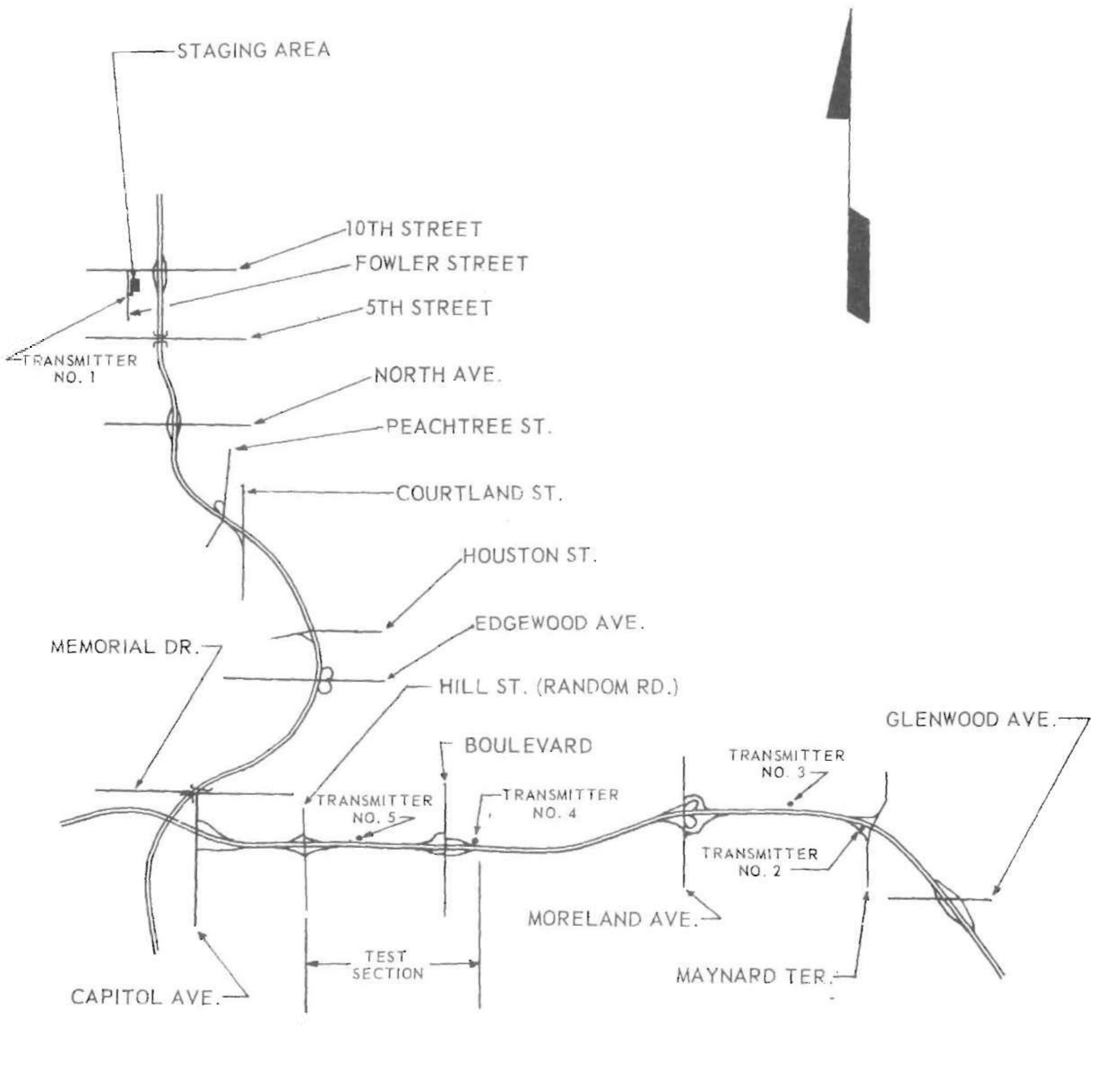

Figure 11. Location Sketch of Staging Area, Test Route, and Test Section.

Transmitters No. 1, 2 and 3 broadcast the same message respectively to all test subjects no matter what test condition was employed for the night. The location of these transmitters and signs not included in the actual experiment, and the type of message given by each are shown in Table 2.

Table 2. Messages Given by Transmitters and Highway Signs Which Were Not Included in the Actual Experiment

Location	Audio Message	Visual Message
Staging Area	Transmitter No. 1: "Information on Actual Roadway Conditions Will be Given to You on East Freeway"	Radio Experiment Atlanta Freeway
Near Maynard Terrace Before Glenwood Off-ramp	Transmitter No. 2: "Turn Around at Glenwood"	Random Road ←
East of Moreland Avenue	Transmitter No. 3: "Use Right Through Lane"	No message

Data Collection Locations

Data collection locations along the test section were at three critical positions as follows:

A. In the vicinity of advance information point (before and after any advance information).

B. In the vicinity of exit information point (before and after any exit information).

C. At the point of entry (beyond exit information at entrance to the exit ramp).

At (A) and (B), data collection was done with the use of traffic analyzers and cameras. At (C), the positions where the test cars entered the deceleration lane were recorded by determining the position of entry of both right and left front wheels with respect to the beginning of the tapered section of the deceleration lane.

To collect data at locations (A) and (B) two traffic analyzers and three cameras were used. One of the traffic analyzers was located at a distance of about 1000 feet west of Boulevard Interchange Structure and was used to collect data on vehicle operating characteristics prior to and after hearing or reading an advance message. Camera No. 1 which was positioned facing the traffic on the overhead structure of Boulevard recorded the passage of vehicles while actual audio or visual advance messages were being given according to test schedule employed. Transmitter No. 4 and highway signs were used to give advance messages at this portion of the test section. Camera No. 2 was positioned on the same overhead structure as Camera No. 1 and recorded the passage of vehicles going away after advance or no information had been given. Camera No. 3 was positioned on the overhead structure of Cherokee Avenue facing traffic and recorded the passage of vehicles along a portion of the test section after advance information and prior to any exit information. The other traffic analyzer was used to collect data during and after any exit information. Exit information was given through Transmitter No. 5 and highway signs. A sketch of the study area with transmitter, camera, analyzer and highway sign locations is shown in Figure 12.

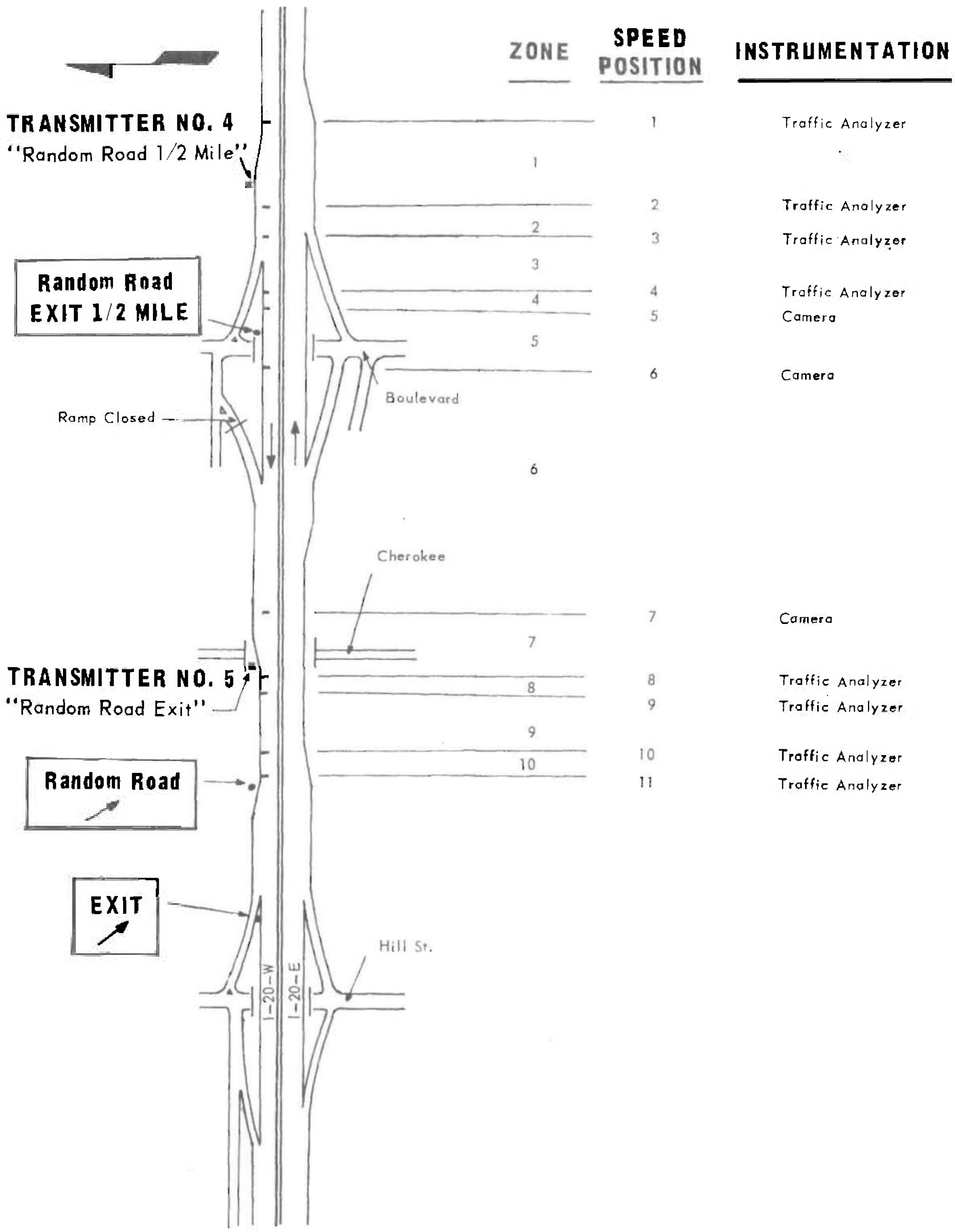

Figure 12. Transmitter, Analyzer, Camera and Highway Sign Locations Along the Test Section.

Highway signs were positioned with respect to transmitters as follows:

Approximately 800 foot antenna loop was employed in giving audio messages. Highway signs were positioned at the end of this loop antenna where audio messages ceased to be given. A study described in reference (12) has shown that the mean nighttime legibility distance of 10 inch white reflectorized letters on a dark, non-reflectorized background under simulated roadway conditions, is about 600 feet. The first message given at the beginning of this 800 foot antenna loop would not usually be understood by most test subjects who would be traveling at about 50 m.p.h. By the time the second message is heard 2 or 3 seconds will have elapsed and this corresponds approximately to a distance of about 200 feet. Thus, the driver will start comprehending the audio message at a distance of about 600 feet from the highway sign. In other words audio messages were given as soon as highway signs became visible to drivers so that each method of communication was comprehended at the same time by the driver. Table 3 shows the location of transmitters and highway signs in the test section and type of message given in the actual experiment.

With the traffic analyzer and cameras it was possible to collect data at eleven positions along the test section. Table 4 shows equipment, speed measurement positions, type of information given at each position, and distance between speed measurement positions employed in data collection.

The nine test conditions employed in the experiment are listed in Table B-1 in the Appendix in order the tests were conducted.

Table 3. Messages Given by Transmitters and Highway Signs Which Were Included in the Actual Experiment

Location	Audio Message	Visual Message
East of Moreland Avenue	Transmitter No. 4: "Random Road 1/2 Mile"	Random Road EXIT 1/2 MILE
Hill Street (Random Road)	Transmitter No. 5: "Random Road Exit"	Random Road ↗ EXIT ↗

Table 4. Type of Information Given and Equipment Used for Data Collection at Various Speed Measurement Positions

Speed Position	Type of Information*	Equipment	Distance Between Speed Positions (Ft.)
1	No Information	Traffic Analyzer	440
2	Advance Information	Traffic Analyzer	160
3	Advance Information	Traffic Analyzer	300
4	Advance Information	Traffic Analyzer	80
5	Advance Information	Camera No. 1	420
6	No Information	Camera No. 2	1170
7	No Information	Camera No. 3	324
8	Exit Information	Traffic Analyzer	100
9	Exit Information	Traffic Analyzer	328
10	Exit Information	Traffic Analyzer	100
11	No Information	Traffic Analyzer	

*According to test schedule employed, no exit information might have been given and in the case of the Control Group (A_0V_0) no information was given along the test section except an exit sign at the gore of the Random Road exit.

CHAPTER III

DATA ANALYSIS

Film Analysis

The film exposed at the three camera locations was analyzed by projecting it through a time and motion study projector which allowed a frame by frame analysis of each roll of film. The film was projected onto a screen upon which a grid was superimposed. This grid was made to exactly fit the grid that was painted on the edges of the pavement.

After a vehicle had been identified as a test vehicle in the camera field of view it was advanced until it crossed the first grid line. Its position was then carefully recorded with respect to the grid line and advanced again until it reached a position within the grid section just before going out of the grid section. The distance it traveled in the grid and the time it took for the vehicle to traverse that section of the grid was carefully determined. Using this technique it was possible to analyze each roll of film for vehicle speeds and travel time.

Traffic Analyzer Data Analysis

One of the traffic analyzers used in the experiment recorded data on adding machine tapes while the other recorded data on punch tapes. The punch tape data were transferred to punch cards for processing.

Each traffic analyzer recorded data at four positions through speed detectors placed on the highway pavement along the test section.

Therefore the tracing of each test vehicle through each of the four positions was necessary, and decoding of the printed or punch tape data yielded the speed and time of each test vehicle at each recording.

Point of Entry Data Analysis

The entry to the deceleration lane was divided into five equal increments of 100 feet in length starting from the beginning of the tapered section of the deceleration lane. An observer recorded the position of entry of both right and left front wheels of each test car as it entered the deceleration lane. Thus it was possible to determine the percentage of test cars entering the deceleration lane at various increments of the deceleration lane under the different test conditions. These data were used to compare the decision-making process of test subjects under different levels of information as they entered the deceleration lane.

Performance Criteria

Film and traffic analyzer data yielded information on speed and travel time of test cars in each test condition. These data were expanded to derive information on acceleration and acceleration noise.

During the data reduction process it was noted that due to camera or traffic analyzer failures and reloading of cameras, certain values of speed for various speed measurement positions were missing. It was decided that if three consecutive values of speed of the eleven values which were possible were missing for any test car, all the values obtained for the car would be eliminated from the analysis. If less than three values were missing, the missing values were estimated. In order to make a reliable estimate of these values, individual plots (Speed vs. distance) were drawn for each test car, lead car, trailing car and for average values of speed for each test condition. These plots gave a reliable estimate of how cars drove along the test section and the missing values were then approximated.

A major factor which caused some of the data to be eliminated from the analysis was the effect of car leading and trailing the test car on the speed of the test car. Several studies on car following theory and data associated with this theory indicated that a definite time limit for the influence of the leading and trailing car on the speed of the test car could not be established. Therefore, the following criteria for the determination of the lead and trail car was established:

(a) Lead car: 6 seconds or less in headway from the test car

(b) Trail car: 2 seconds or less in headway from the test car.

If a car was leading or trailing a test car within the time limits established, it was eliminated from the analysis. However, because a specific car may not be a leading or trailing car for the entire test section, a portion of the data was of use and the entire data for the test car was not eliminated in the entire test section. This procedure led to the analysis of the entire section as a unit and two increments of the test section in the (a) vicinity of advance information point, and (b) vicinity of exit information point. Table B-2 in the Appendix shows the number of test vehicles for which data was obtained during each test condition and the number of vehicles for which data could be used in the analysis for each test condition. Of the 310 test cars which participated in the experiment, only 121 cars could be used for the entire test section, 141 cars for the vicinity of advance information point and 147 cars for the vicinity of exit information point.

In order to evaluate driver performance and behavior under various conditions of information several criteria were selected as "ideal standards" and these are as follows:

1. In the vicinity of advance information point:

   Deceleration should approach zero;

$$d_a = \frac{dv}{dt} \rightarrow 0 \text{ (Speed constant)} \tag{1}$$

2. In the vicinity of exit information point:

   Deceleration should approach zero;

$$d_b = \frac{dv}{dt} \rightarrow 0 \text{ (Speed constant)} \tag{2}$$

3. At the point of entry:

   Entry into the deceleration lane should be at earliest possible;

$$(P_E - P_T) \rightarrow 0 \tag{3}$$

   where P_E = point of entry

   P_T = point of taper

4. Acceleration noise along the test section should approach zero;

$$\sigma_a^2 = \frac{1}{T} \int_0^T (a_t - \bar{a}_t)^2 \, dt \rightarrow 0 \tag{4}$$

where σ_a = acceleration noise

T = time duration of travel over test section

a_t = acceleration of a car at time t

$\bar{a}_t$ = average acceleration of the car over test section.

5. The average value for travel time of the control group test condition could be used as an "ideal" overall travel time.

Comparisons

Several comparisons were made among test conditions under various information:

(a) A comparison of driver performance among groups having seen or heard visual, audio or visual and audio advance information.

(b) A comparison of driver performance among test groups having seen or heard visual, audio, or visual and audio advance and exit information. The control group, A_0V_0, has been included in the comparison in both (a) and (b).

(c) A comparison of the effect of audio messages, sign messages and combination of these two modalities on the decision-making process of test drivers on entry into the deceleration lane.

(d) In certain instances, the Control Group, A_0V_0, was used as a basis of comparison, but not as an "ideal standard."

Statistical Analysis

(a) Speed and Acceleration: After individual speeds were obtained at various positions along the test section the rates of acceleration were computed for ten zones consisting of increments of the test section between consecutive speed measurement positions. These acceleration rates were computed on the basis of initial velocity, final velocity and distance traversed. For this purpose, the decimal timer of the Traffic Analyzer and the time basis of the film frame intervals lacked sufficient accuracy. The relationship used is as follows:

$$\text{Acceleration} = \frac{(v_2)^2 - (v_1)^2}{2S} \qquad (5)$$

where v_1 = initial velocity

v_2 = final velocity

S = distance traversed

Prior to the analysis of variance for speed and acceleration, the assumption of the hypothesis of equal variances of data was investigated using Barlett's test. These tests indicated that the hypothesis of equal variances was acceptable at 10 per cent level of significance. Because of the unequal number of test subjects in each test group, the standard analysis of variance technique was not applicable. The analysis of variance used for the non-orthogonal data is described in detail in reference(10). A summary of the description of the analysis technique used is given below:

An estimate of the common variance was obtained by pooling the sums of squares within all the sub-classes. Homogeneity of the data was then tested by calculating estimates of variance of each sub-class separately and comparing them with the common variance. If homogeneity was rejected in favor of the additive effect of classes expressed by the usual hypothesis, the sum of squares between all classes was split into independent sums related to the fitting of the constants and into an interaction term which in turn was compared with the common variance to test for interaction.

Further investigation was made on the mean of those factors where significant differences were indicated subsequent to the analysis of variance. In order to judge all contrasts in this analysis Scheffe's method was used because of the unequal cell sizes. All contrasts were determined at the 10 per cent level instead of the usual 5 per cent and 1 per cent levels because of the large variabilities involved in traffic data.

(b) Acceleration noise: To make a qualitative comparison among various test groups this traffic parameter has been computed from data obtained along the test section. Continuous data on speed-time relationship, which enable the computation of acceleration noise as defined in equation (4) were collected at the eleven speed positions.

If a car's final speed is the same as its initial speed, $\bar{a}_t = 0$. Also, for any prolonged journey $\bar{a}_t$ approaches zero and in most cases it is comparatively small and can be neglected. Thus, acceleration noise is normally calculated by the equation

$$\sigma_a^{\ 2} = \frac{1}{T} \int_0^T a_t^{\ 2} \ (dt) \qquad (6)$$

In this study acceleration noise has been computed using data on speed and travel time obtained at eleven speed measurement positions along the test section. It was assumed that acceleration between two speed measurement positions would be constant and therefore an estimate of acceleration noise was obtained by approximating equation (6) by the following formula:

$$\sigma_a^2 = \frac{1}{T} \sum_{i=1}^{n} a(t)_i^2 \cdot \Delta t_i \tag{7}$$

where $a(t)$ = acceleration at an increment of the test section

t_i = travel time between consecutive speed measurement positions

n = number of increments of test section.

(c) Overall travel times: As in the case of accelerations, travel times were computed on the basis of initial velocity, final velocity and distance traversed using the following relationship:

$$T = \sum_{i=1}^{n} \frac{S_i}{1/2(v_i + v_{i+1})} \tag{8}$$

where S_i = distance traversed between consecutive speed positions or in each zone

v_i = speed measured at the i^{th} speed position

n = number of increments or zones in the test section

T = time duration of travel over the entire section

Statistical analysis made for the data computed for acceleration noise and overall travel times, was through the usual techniques of analysis of variance for a one-way classification experimental design.

CHAPTER IV

RESULTS OF DATA ANALYSIS

The results of the analysis of variance and multiple range tests employed for various comparisons of speed and acceleration are shown for the entire test section, vicinity of advance information point and the vicinity of exit information point.

Analysis of Variance - Vehicle Speeds

The following comparisons show the rank order and significant differences between the various test and control groups for mean speed in miles per hour. There are no significant differences between the mean speed of those test conditions underlined. Level of significance used is 10 per cent.

A. Test Conditions

1. All test conditions

   (a) Entire test sections

   Test Condition

A_2V_0	A_1V_2	A_2V_2	A_0V_0	A_0V_2	A_1V_1	A_1V_0	A_2V_1	A_0V_1

   Mean Speed

49.44	49.44	48.90	48.74	48.35	47.78	47.51	45.44	45.41

(b) Vicinity of advance information point (positions 1 through 6)

Test Condition

$A_1V_{(2)}$* $A_{(2)}V_0$ $A_0V_{(2)}$ $A_{(2)}V_{(2)}$ A_0V_0 A_1V_0 A_1V_1 $A_{(2)}V_1$ A_0V_1

Mean Speed

50.08 49.23 48.49 48.38 48.33 48.31 47.63 46.67 46.33

(c) Vicinity of exit information point (positions 6 through 11)

Test Condition

A_0V_0 A_2V_2 A_2V_0 A_1V_1 A_1V_2 A_1V_0 A_0V_2 A_0V_1 A_2V_1

Mean Speed

51.54 49.75 49.68 48.92 48.88 48.06 47.42 45.65 44.60

2. Test conditions involving advance information and the control group, A_0V_0

(a) Entire test section

Test Condition

A_0V_0 A_1V_1 A_1V_0 A_0V_1

Mean Speed

48.74 47.78 47.51 45.41

(b) Vicinity of advance information point (positions 1 through 6)

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*The subscript 2 in parentheses indicates that although two messages were given for that particular test condition, measurements were taken in the vicinity of advance information point and therefore no exit information had been given yet (e.g. $A_{(2)}V_1 = A_1V_1$).

Test Condition

A_0V_0 A_1V_0 A_1V_1 A_0V_1

Mean Speed

48.33 48.31 47.63 46.33

(c) Vicinity of exit information point (positions 6 through 11)

Test Condition

A_0V_0 A_1V_1 A_1V_0 A_0V_1

Mean Speed

51.54 48.92 48.06 45.65

3. Test conditions involving both advance and exit information and the control group, A_0V_0

(a) Entire test section

Test Condition

A_2V_0 A_1V_2 A_2V_2 A_0V_0 A_0V_2 A_2V_1

Mean Speed

49.44 49.44 48.90 48.74 48.35 45.55

(b) Vicinity of advance information point (positions 1 through 6)

Test Condition

$A_1V_{(2)}$ $A_{(2)}V_0$ $A_0V_{(2)}$ $A_{(2)}V_{(2)}$ A_0V_0 $A_{(2)}V_1$

Mean Speed

50.08 49.23 48.49 48.38 48.33 46.67

(c) Vicinity of exit information point (positions 6 through 11)

Test Condition

A_0V_0 A_2V_2 A_2V_0 A_1V_2 A_0V_2 A_2V_1

Mean Speed

51.54 49.75 49.68 48.88 47.42 44.60

In the above analysis it can be seen that test condition A_2V_1 had a relatively low average speed as compared to test conditions with about the same amount of information. This was an unexpected result as it consisted of almost maximum information and a better performance was expected of test subjects participating in this test condition. However, volume counts made during the nights of the experiment showed a relatively high volume (1,116 vehicles/hr) for test condition A_2V_1 as compared with the average volume of 861 vehicles per hour for other test conditions. The film analysis has also shown that cars approached the test section in platoons and traveled through in the same manner. The low speeds of test condition A_2V_1 and any contradictions in the results of the analysis may be due to the fact that for this particular night, test subjects might have been under the influence of the general traffic.

In the comparison of mean vehicle speeds of the nine test conditions employed in the experiment for the entire test section, the results of the analysis of variance and multiple range tests indicated that the performance of test subjects in all test conditions except A_2V_1 and A_0V_1, did not significantly differ from each other and that of the control group. Test vehicles in test conditions A_2V_1 and A_0V_1 had different performances by being significantly different from those in test conditions

A_2V_0, A_1V_2, A_2V_2 and A_0V_2 which had higher mean speeds and closer to that of the control group.

In the vicinity of advance information point the performance of all test subjects was not significantly different from the control group no matter what guidance information was given. However, test conditions $A_{(2)}V_1$, and A_0V_1 with lower mean speeds were significantly different from test condition $A_1V_{(2)}$.

In the vicinity of exit information point test vehicles in test conditions A_1V_0 and A_0V_1 with only one level of advance information had lower mean speeds and differed significantly from the control group while test conditions with two or more messages, except A_2V_1 and A_0V_2 did not differ significantly. The different behavior of A_2V_1 has already been explained but in the case of A_0V_2, this may well have been an indication of the reaction of drivers to conventional highway signing. In other words, visual exit information caused a greater reduction in the speed of test subjects than audio exit information. Test conditions A_0V_1 and A_2V_1 were also found to have significantly lower speeds than test conditions A_2V_2 and A_2V_0 for this area of the test section.

These comparisons of mean speeds of all test conditions with respect to the entire test section and portions of the test section indicated that except for test conditions A_2V_1 and A_0V_2 test subjects in test conditions with both advance and exit information had higher mean speeds than test subjects in test conditions with less information. This indicated that well informed test drivers did not have to travel at low speeds in search for the exit ramp.

Similarly, vehicles in the control group had speeds comparable to those in test conditions with substantial information. Vehicles in the control group were not given any information at all along the test section. These vehicles drove normally along the test section and no uncertainty was involved as to the location of the exit ramp at the end of the test section.

When comparing the behavior of test subjects with only advance information and the control group for the entire test section, test condition A_0V_1 was significantly different from test conditions A_0V_0 and A_1V_1, and once again showing a different performance with a lower mean speed as compared to other test conditions. In the vicinity of advance information point, speeds in all test conditions had no significant differences between each other and the control group. In the vicinity of exit information point, however, all test conditions showed different performances by having significantly lower speeds than that of the control group. Test condition A_0V_1 was also significantly different from test condition A_1V_1 while test condition A_1V_0 was not. Test subjects in these test conditions had already received advance guidance information about the exit. Because no information was given in the vicinity of the exit this condition may have caused some uncertainty as to the location of the off-ramp. This uncertainty is indicated by these test conditions having significantly lower mean speeds than the mean speed of test subjects in the control group, A_0V_0, who had not received any information at all and were not expecting to exit from the freeway.

In the analysis of speed data for test conditions involving both advance and exit information and control group, the mean speed of these test conditions for the entire test section did not differ from each other and the control group except for test condition A_2V_1 which had a significantly lower speed than other test conditions.

In the vicinity of the exit information point no test condition was significantly different from the control group but test condition $A_{(2)}V_1$ was significantly different from test conditions $A_1V_{(2)}$ and $A_{(2)}V_{(2)}$. The different performance of test condition $A_{(2)}V_1$ is evident again, for this portion of the test section.

In the vicinity of exit information point test condition A_2V_1 was significantly different from all test conditions and the control group. Test condition A_0V_2 showed a different performance as compared to the control group by having a significantly lower speed. This test condition was not significantly different from the control group in the vicinity of the advance information point and indicates the slowing down of test subjects on the freeway prior to the deceleration lane.

B. Speed Measurement Positions

1. Entire test section

(a) All test conditions

Position	6	7	1	8	4	9	5	10	3	11	2
Mean Speed	50.37	50.16	48.52	48.18	48.12	47.96	47.83	47.60	46.64	46.07	45.57

(b) Test conditions with advance information and control group:

A_0V_1, A_1V_0, A_1V_1 and A_0V_0

Position	6	7	4	10	8	9	1	5	11	3	2
Mean Speed	50.53	49.98	47.84	47.55	47.51	47.49	47.39	47.08	46.08	45.76	44.41

(c) Test conditions with both advance and exit information and control group: A_0V_2, A_2V_0, A_1V_2, A_2V_1, A_2V_2 and A_0V_0

Position	7	6	1	8	3	9	4	5	10	11	2
Mean Speed	50.60	50.50	49.10	48.67	48.51	48.40	48.32	48.24	47.85	46.36	46.32

2. Vicinity of advance information point

(a) All test conditions*

Position	6	1	4	5	3	2
Mean Speed	50.65	48.86	48.35	47.87	47.01	45.91

(b) Test conditions with advance information and control group:

(A_0V_1, A_1V_0, A_1V_1 and A_0V_0)

Position	6	4	1	5	3	2
Mean Speed	50.88	48.34	47.98	47.63	46.22	45.05

*Although some of the test conditions employed involve both advance and exit information, test subjects had not yet received any exit information.

(c) Test conditions with advance and exit information and control group*: $(A_0V_{(2)}, A_{(2)}V_0, A_1V_{(2)}, A_{(2)}V_{(1)}, A_{(2)}V_{(2)}$ and $A_0V_0)$

Position

6 1 4 5 3 2

Main Speed

50.67 49.39 48.38 47.97 47.59 46.50

3. Vicinity of exit information point

(a) All test conditions

Position

7 6 8 9 10 11

Main Speed

50.01 49.88 48.07 47.90 47.64 46.09

(b) Test conditions with advance information and control group:

$(A_0V_1, A_1V_0, A_1V_1$ and $A_0V_0)$

Position

6 7 10 8 9 11

Mean Speed

50.69 50.52 48.20 48.09 48.00 46.55

*Although some of test conditions employed involve both advance and exit information, test subjects had not yet received any exit information.

(c) Test conditions with both advance and exit information and control group: (A_0V_2, A_2V_0, A_1V_2, A_2V_1, A_2V_2 and A_0V_0)

Position

7	6	8	9	10	11

Mean Speed

50.51	49.97	48.49	48.31	47.92	46.29

The analysis of variance and multiple range tests for average speeds at the eleven speed measurement positions showed that there were significant differences between critical positions (positions where some kind of information was being given) and various other positions. The location of the various speed positions are shown in Figure 9 and Table 4 shows type of information given at each of these positions.

The comparison of mean speeds at the eleven speed measurement positions along the test section indicated that mean speeds at positions 6 and 7 were significantly different from those at position 2, 3 and 11. Positions 6 and 7 were located after advance information had been given and had higher speeds than positions 2 and 3, located during advance information, and 11 located after exit information. It was also found that the approaching speed at position 1 was not significantly different from positions 6 and 7, thus indicating that test subjects showed a tendency to slow down after they received advance and exit information.

When only advance information was given mean speeds at positions 6 and 7 were again significantly higher from that at position 2, but not from that at position 11. When test conditions with both advance and exit information were compared, test subjects showed the same reaction to information given as indicated by the significant differences in speeds. Positions 6 and 7 had significantly higher speeds than those at positions 2 and 11.

In the vicinity of advance information point which included positions 1 through 6 and in the vicinity of exit information point which included positions 6 through 11 the slowing down of test vehicles was evidenced as indicated by the significant differences between positions after advance and before any exit information and positions during advance information and after exit information.

Although no definite conclusions could be derived from the analysis of speeds at the speed measurement positions as to which test conditions caused these significant differences it could be seen that these differences were due to the fact that some sort of information was given. The test subjects approached the test section at a certain speed, then a reduction in speed was noticed after receiving advance information. The test subjects then increased their speeds towards the middle of the test section after which they again slowed down after exit information was given in order to enter the deceleration lane.

Tables C-1, C-2 and C-3 in the Appendix show the mean speeds of each test condition for every position. It can be seen that mean speeds at position 2, which is the beginning of advance information point, were slower than at position 1 where approaching speeds were recorded. Traffic again reduced speed after position 7 where exit information was being given.

Other analysis of variance tests made for each position with respect to all test conditions did not show any significant differences between any of the test conditions. Table C-4 in the Appendix shows the rank order for speeds at the various positions for each test.

Analysis of Variance - Rates of Acceleration

Rank order and significant differences for acceleration in ft/sec^2 are shown below for various test conditions. A 10 per cent significance level is used in all cases. There are no significant differences between those conditions underlined.

A. Test Conditions

1. All test conditions

(a) Entire test section

Test Condition

A_2V_2 A_1V_2 A_1V_0 A_2V_0 A_2V_1 A_0V_1 A_0V_0 A_1V_1 A_0V_2

Mean Acceleration

0.093 0.051 -0.045 -0.183 -0.201 -0.210 -0.250 -0.255 -0.659

(b) Vicinity of advance information point (positions 1 through 6)

Test Condition

$A_1V_{(2)}$ $A_{(2)}V_{(2)}$ A_1V_0 $A_{(2)}V_0$ A_0V_1 A_0V_0 A_1V_1 $A_{(2)}V_1$ $A_0V_{(2)}$

Mean Acceleration

0.642 0.558 0.449 0.209 0.105 0.058 -0.113 -0.302 -0.404

(c) Vicinity of exit information point (positions 6 through 11)

Test Condition

A_2V_1 A_2V_2 A_0V_1 A_1V_1 A_1V_2 A_1V_0 A_2V_0 A_0V_0 A_0V_2

Mean Acceleration

-0.224 -0.372 -0.416 -0.459 -0.509 -0.545 -0.584 -0.659 -0.744

2. Test conditions with advance information and control group, A_0V_0

(a) Entire test section

Test Condition			
A_1V_0	A_0V_1	A_0V_0	A_1V_1
Mean Acceleration			
-0.045	-0.210	-0.250	-0.255

(b) Vicinity of advance information point (positions 1 through 6)

Test Condition			
A_1V_0	A_0V_1	A_0V_0	A_1V_1
Mean Acceleration			
0.449	0.105	0.058	-0.113

(c) Vicinity of exit information point (positions 6 through 11)

Test Condition			
A_0V_1	A_1V_1	A_1V_0	A_0V_0
Mean Acceleration			
-0.416	-0.459	-0.545	-0.659

3. Test conditions with both advance and exit information

(a) Entire test section

Test Condition					
A_2V_2	A_1V_2	A_2V_0	A_2V_1	A_0V_0	A_0V_2
Mean Acceleration					
0.093	0.051	-0.183	-0.201	-0.250	-0.659

(b) Vicinity of advance information point (positions 1 through 6)

Test Condition

$A_1V_{(2)}$	$A_{(2)}V_{(2)}$	$A_{(2)}V_0$	A_0V_0	$A_{(2)}V_1$	$A_0V_{(2)}$

Mean Acceleration

0.642	0.558	0.209	0.058	-0.302	-0.404

(c) Vicinity of exit information point (positions 6 through 11)

Test Condition

A_2V_1	A_2V_2	A_1V_2	A_2V_0	A_0V_0	A_0V_2

Mean Acceleration

-0.224	-0.372	-0.509	-0.584	-0.659	-0.744

The data analysis for mean rates of acceleration of test subjects indicated similar results as the speed data. In the analysis of variance and multiple range tests it was found that average accelerations for the entire test section did not differ significantly from the control group. However, test condition A_0V_2 with the highest rate of deceleration was significantly different from test conditions A_2V_2 and A_1V_2. Test conditions A_2V_2, A_1V_2, A_1V_0, A_2V_0 and A_2V_1 had acceleration or decelerations closer to zero than other test conditions, thus indicating a better performance than the other test conditions. It is interesting to note that these test conditions include either audio messages or visual messages supplemented by audio messages.

In the vicinity of the advance information point mean acceleration rate of test condition $A_0V_{(2)}$ was significantly different from those of test conditions $A_1V_{(2)}$ and $A_{(2)}V_{(2)}$ but none were significantly different from that of the control group. Test conditions which gave accelerations closer to zero than others were $A_{(2)}V_0$, A_0V_1, A_0V_0 and A_1V_1. This condition indicated that advance information could be given with any mode of communication and the results would not be significantly different from each other.

In the vicinity of exit information point no test condition was significantly different from each other and the control group and all were decelerations. These data indicate that test subjects reduced speed on the freeway before entering the deceleration lane.

When tests with only advance information were compared with respect to the entire test section and vicinity of advance and exit information points, no significant differences were found to exist between any of the test conditions and control group.

When comparing test conditions with both advance and exit information it was found that for the entire test section these test conditions were not significantly different from the control group but test condition A_0V_2 differed significantly from test conditions A_2V_2 and A_1V_2. These two test conditions had accelerations closer to zero and a better performance. In the vicinity of the advance information point no test condition was significantly different from the control group which had a mean rate of acceleration closer to zero than all other test conditions. Test condition $A_0V_{(2)}$ was however significantly different from test conditions $A_1V_{(2)}$ and $A_{(2)}V_{(2)}$ with the former having a higher rate of deceleration and the latter having higher rates of acceleration as compared to other test conditions. Test condition $A_1V_{(2)}$ was also significantly different from test condition $A_{(2)}V_1$. These data indicate that no decisions can be made as to which test condition produced better performance in the vicinity of advance information point.

There were no significant differences found between any of the test conditions and control group in the vicinity of exit information point.

B. Acceleration Zones

Acceleration zone indicates the distance between consecutive speed measurement positions. These zones can be seen in Figure 9. Rank order and significant differences for acceleration between these zones are shown as follows:

1. All test conditions

(a) Entire test section

Zone	5	2	3	6	9	8	4	7	1	10
Mean Acceleration	0.653	0.646	0.494	-0.008	-0.048	-0.301	-0.404	-0.627	-0.656	-1.594

(b) Vicinity of advance information point (zones 1 through 5)

Zone	2	5	3	1	4
Mean Acceleration	0.665	0.629	0.449	-0.660	-0.685

(c) Vicinity of exit information point (zones 6 through 10)

Zone	6	9	8	7	10
Mean Acceleration	-0.005	-0.034	-0.245	-0.617	-1.606

2. Test conditions with advance information and control group (A_0V_1, A_1V_0, A_1V_1 and A_0V_0)

(a) Entire test section

Zone	5	3	2	9	8	6	1	7	4	10
Mean Acceleration	0.952	0.859	0.776	0.073	-0.016	-0.032	-0.643	-0.786	-1.211	-1.773

(b) Vicinity of advance information point (zones 1 through 5)

Zone	5	3	2	1	4
Mean Acceleration	0.845	0.719	0.678	-0.639	-1.201

(c) Vicinity of exit information point (zones 6 through 10)

Zone	9	6	8	7	10
Mean Acceleration	0.058	0.004	-0.096	-0.792	-1.777

3. Test conditions with advance and exit information and control group

(a) Entire test section

Zone	5	2	3	6	9	4	8	7	1	10
Mean Acceleration	0.586	0.408	0.340	0.015	-0.072	-0.078	-0.380	-0.617	-0.630	-1.612

(b) Vicinity of advance information point (zones 1 through 5)

Zone	2	5	3	4	1
Mean Acceleration	0.687	0.571	0.258	-0.497	-0.638

(c) Vicinity of exit information point (zones 6 through 10)

Zone	6	9	8	7	10
Mean Acceleration	0.015	-0.046	-0.148	-0.652	-1.624

The significant differences between accelerations for various increments of the test section are as shown above. No decisions could be made to indicate which of the test conditions caused the various significant differences between these zones as they are the results of all or various test conditions combined together. As it was with the speeds at the various positions, the slowing down of test subjects as a result of some kind of information given to them was evidenced. Zone 1 had always a deceleration and generally from zone 2 to about 6 there would be an acceleration. After zone 6 the test cars would decelerate reaching maximum deceleration at zone 10 just before exiting the freeway.

Tables C-5, C-6 and C-7 in the Appendix show rates of acceleration in each zone for each test condition employed in the experiment. These tables also indicate the reduction of speeds of test subjects just after receiving an advance guidance or exit information.

Other statistical analysis of rates of acceleration in each zone with respect to test and control groups indicated that there were no significant differences between the rates of acceleration in zones 1, 2,3,6,7,9 and 10. The significant differences found were at zones 4, 5 and 8. Rank order and significant differences between test and control groups at the various zones for rates of acceleration are shown in Table C-8 in the Appendix. Zones 4 and 5 fall within that portion of the test section along which advance information was being given. Zone 8 is the beginning of the latter portion of the test section along which exit information was being given.

In zone 4, test condition $A_0V_{(2)}$ was found to be significantly different from test condition $A_{(2)}V_{(2)}$, the former having a high rate of deceleration and the latter a high rate of acceleration as compared to other test conditions. Test conditions $A_{(2)}V_0$ and A_1V_0 had rates of acceleration which were closer to zero than other test conditions, thus having rather more constant speeds than others.

In zone 5, test conditions $A_{(2)}V_1$ and $A_1V_{(2)}$ were significantly different from test condition A_0V_0 and had rates of acceleration closer to zero thus indicating a better performance than other test conditions.

In zone 8, test conditions A_2V_1 and A_0V_0 were significantly different from test condition A_0V_2 which had a high rate of deceleration and indicated a poor performance. For this zone, which is the beginning of the vicinity of exit information point, test condition A_2V_2, A_2V_0 and A_1V_0 gave rates of acceleration or deceleration lower than all other test conditions and closer to zero. These test conditions indicated better performance within this zone than other test conditions having greater value for acceleration.

Acceleration Noise

The rates of acceleration noise as shown in Tables 5 and 6, have been computed for each test condition by using accelerations and travel times of each zone of the test section between speed measurement positions. Individual values computed for zones of each test condition when added, gave a value for acceleration noise.

An analysis of variance and multiple range test for acceleration noise showed significant differences between some of the test conditions employed. The rank order and significant differences at the 10 per cent level between test and control groups are shown below.

Test Condition	A_0V_2	A_0V_0	A_1V_1	A_1V_2	A_1V_0	A_2V_2	A_0V_1	A_2V_1	A_2V_0
Mean Acceleration Noise ($\bar{\sigma}_a$ = ft/sec^2)	1.70	1.30	1.20	1.09	0.98	0.92	0.89	0.89	0.88

Test conditions with two audio messages had more favorable rates for acceleration noise than test conditions with two visual messages. Test condition A_0V_2 had the largest rate of acceleration noise and was found to be significantly different from test conditions A_2V_2, A_0V_1, A_2V_0. Test condition A_0V_0 had a lower rate of acceleration noise than A_0V_2 because most of the test subjects had missed the ramp and therefore may have not changed their rates of acceleration in the vicinity of the exit ramp. However, test condition A_0V_0 had the highest rate of deceleration at zone 10

Table 5. Acceleration Noise - In Order of Magnitude

Test	Redundancy of Information	No. of Test Cars	Mean Travel Time (sec.)	Mean Acceleration Noise ($\bar{\sigma}_a$ = ft/sec^2)
A_0V_2	2	12	48.49	1.70
A_0V_0	0	12	47.65	1.30
A_1V_1	2	17	49.21	1.20
A_1V_2	3	12	47.42	1.09
A_1V_0	1	11	48.69	0.98
A_2V_2	4	14	47.67	0.92
A_0V_1	1	11	51.50	0.89
A_2V_1	3	16	51.51	0.89
A_2V_0	2	16	46.79	0.88

Table 6. Acceleration Noise - In Order of Redundancy of Information

Test	Redundancy of Information	No. of Test Cars	Travel Time (sec.)	Mean Acceleration Noise ($\bar{\sigma}_a$ = ft/sec^2)
A_0V_0	0	12	47.65	1.30
A_0V_1	1	11	51.50	0.89
A_1V_0	1	11	48.69	0.98
A_0V_2	2	12	48.49	1.70
A_1V_1	2	17	49.21	1.20
A_2V_0	2	16	46.79	0.88
A_1V_2	3	12	47.42	1.09
A_2V_1	3	16	51.51	0.89
A_2V_2	4	14	47.67	0.92

which is the zone prior to entry into the deceleration lane. For this particular zone test condition A_0V_0 had the highest rate of acceleration noise for those test subjects which exited the freeway at the end of the test section.

Figure 13 shows a comparison of rates of acceleration noise for the various test conditions employed in the experiment.

Travel Time

Travel times for the various test conditions employed in the experiment are shown in Tables 5 and 6. An analysis of variance did not show any significant differences at the 10 per cent level, between the various test conditions and the control group. Mean travel times varied from 46.79 seconds to 51.51 seconds. Figure 14 shows a comparison of travel times in order of magnitude and level of information given.

Point of Entry Data

Although the position of entry of both front wheels into the deceleration lane was recorded, the right front wheel was used as the entry indicator. Therefore, the position of the right front wheel shows the distance from the point of taper just after a decision to enter the deceleration lane has been made. The position of the left front wheel indicates the complete entry of test cars into the deceleration lane.

Table 7 shows the per cent of cars for each test condition entering the deceleration lane at various increments of the deceleration lane.

Values in Table 7 indicate that test subjects behaved differently on entry into the deceleration lane according to the amount of information given to them. About 69 per cent of the test subjects participating in

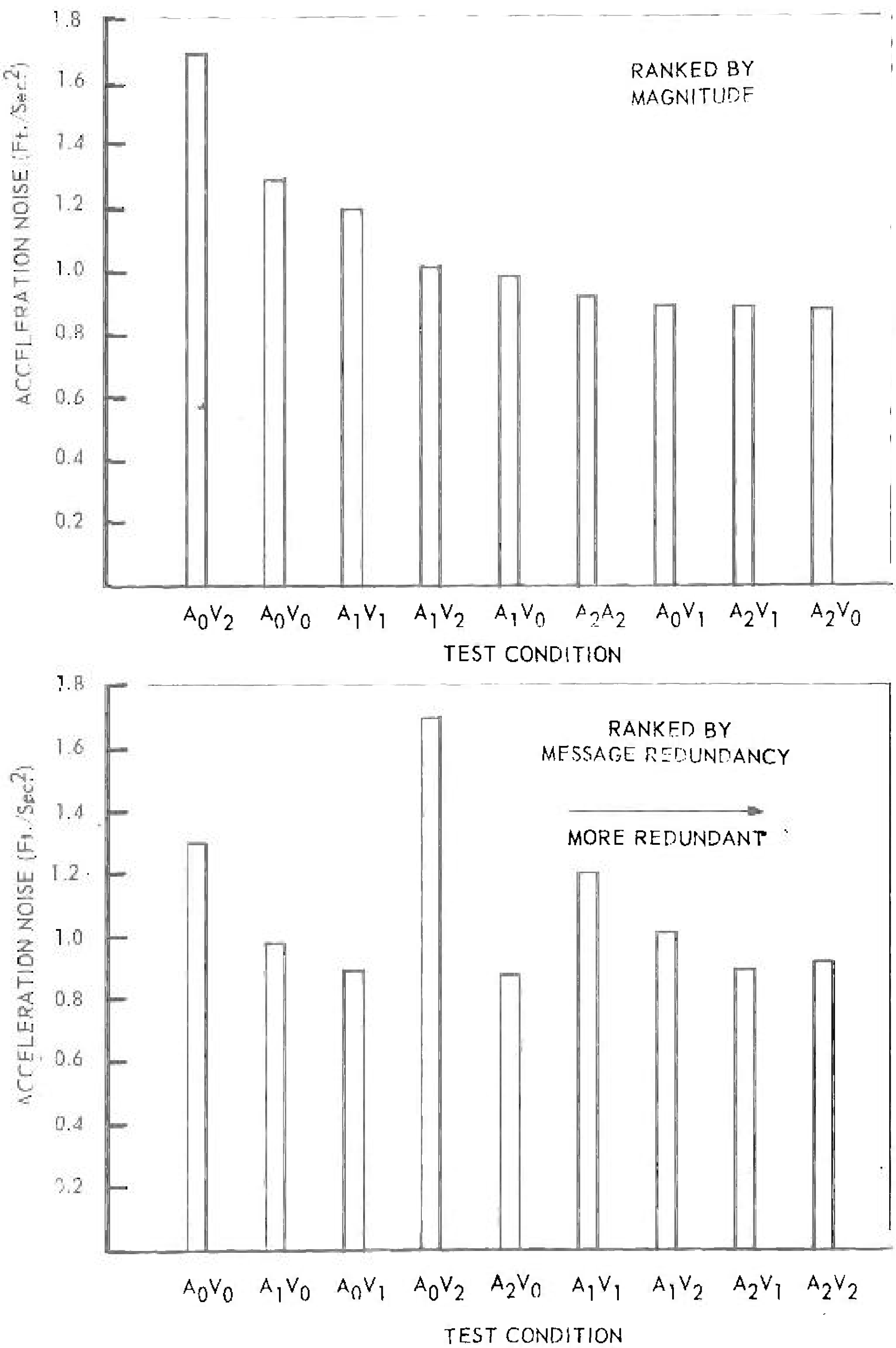


Figure 13. Comparison of Rates of Acceleration Noise for Test Conditions Employed in the Experiment.

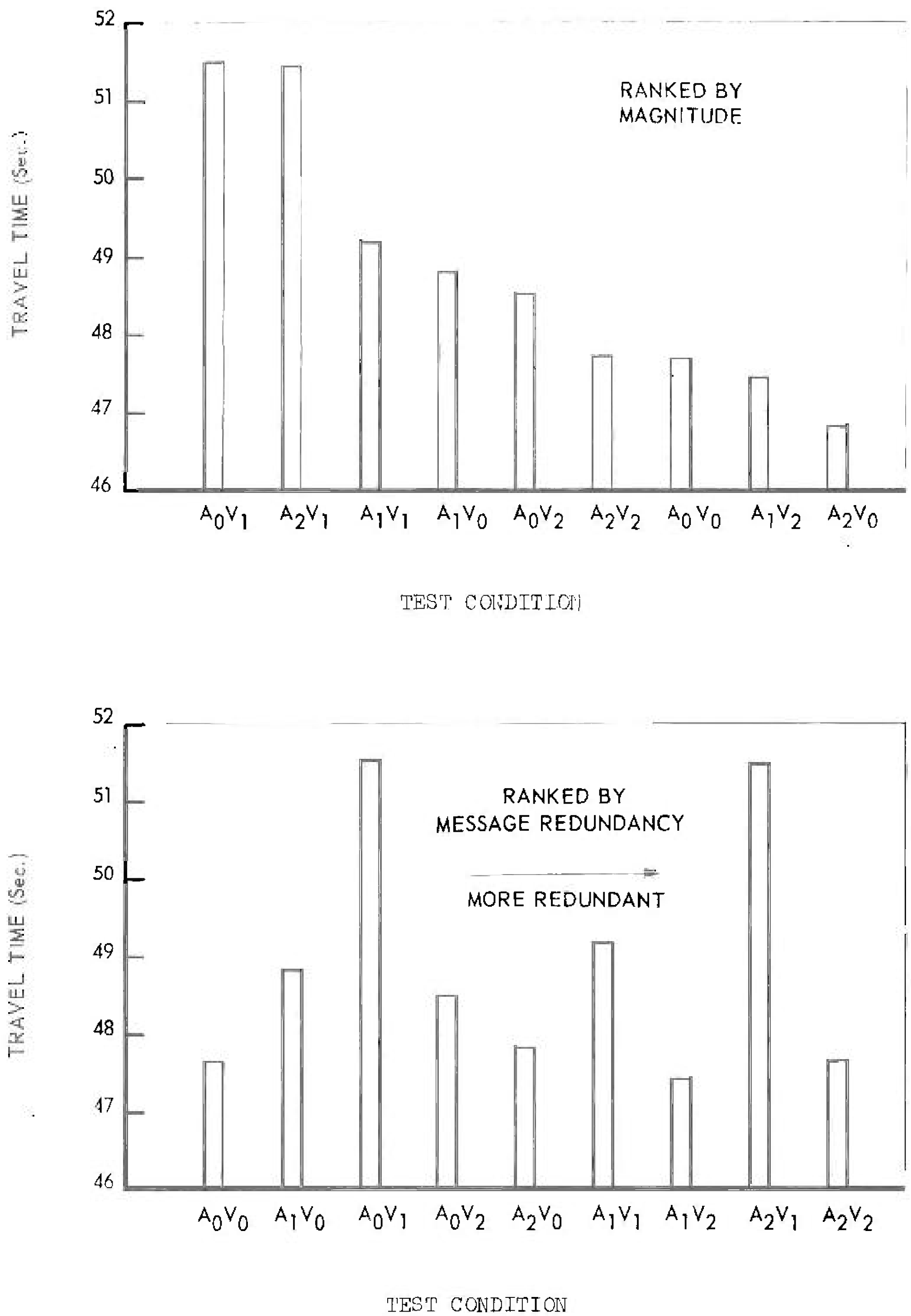


Figure 14. Comparison of Travel Time for Test Conditions Employed in the Experiment.

Table.7. Per Cent of Test Cars Entering the Deceleration Lane at Various Increments of the Deceleration Lane

	Distance from the Point of Taper										
	0-100 feet % entry of front wheel		100-200 feet % entry of front wheel		200-300 feet % entry of front wheel		300-400 feet % entry of front wheel		400-500 feet % entry of front wheel		% of test cars failing to exit at
Test condition and level of information	right	left	right	left	right	left	right	left	right	left	"Random Road"
A_0V_0	0	0	6.25	0	6.25	6.25	18.75	6.25	0	18.75	68.75
A_0V_1	13.33	0	33.33	13.33	33.34	13.34	6.67	40.00	0	20.00	13.33
A_1V_0	0	0	14.29	0	28.57	7.15	21.43	28.57	0	28.57	35.71
A_1V_1	5.56	0	22.22	0	22.22	33.33	44.44	38.89	0	22.22	5.56
A_0V_2	23.53	0	47.06	5.88	23.53	41.18	5.88	41.18	0	11.76	0
A_2V_0	30.00	0	50.00	15.00	15.00	45.00	5.00	30.00	0	10.00	0
A_1V_2	41.67	0	41.67	16.67	16.66	58.33	0	25.00	0	0	0
A_2V_1	40.00	0	50.00	5.00	10.00	75.00	0	20.00	0	0	0
A_2V_2	57.14	0	35.71	28.57	7.15	50.00	0	21.43	0	0	0

test condition A_0V_0 missed "Random Road" exit merely because the only message given to them was the sign at the gore of the exit ramp. Sixty per cent of those in test condition A_0V_0 who exited, entered the deceleration lane at a distance between 300 and 400 feet from the beginning of the taper.

As the amount of information being given was increased it was found that the entry of test subjects into the deceleraion lane was made closer to the point of taper. In test condition A_2V_2, 57 per cent of the test subjects entered the deceleration lane within the first 100 feet from the point of taper. These values were 50%, 42%, 30% and 23% for the test conditions A_2V_1, A_1V_2, A_2V_0 and A_0V_2 respectively. It can also be seen that the entry of left front wheel, i.e. complete entry of cars into the deceleration lane followed the same pattern as the right front wheel.

In every case where only advance information was given it was found that there were test cars missing the exit ramp. No cars missed the ramp when any one of the messages was exit information.

Figure 15 shows the median per cent of test cars entering the deceleration lane for the various test conditions employed in the experiment. The per cent of entry of test subjects into the deceleration lane for each condition at the various increments of the deceleration lane are shown in Figure D-1 through D-18 in Appendix D.

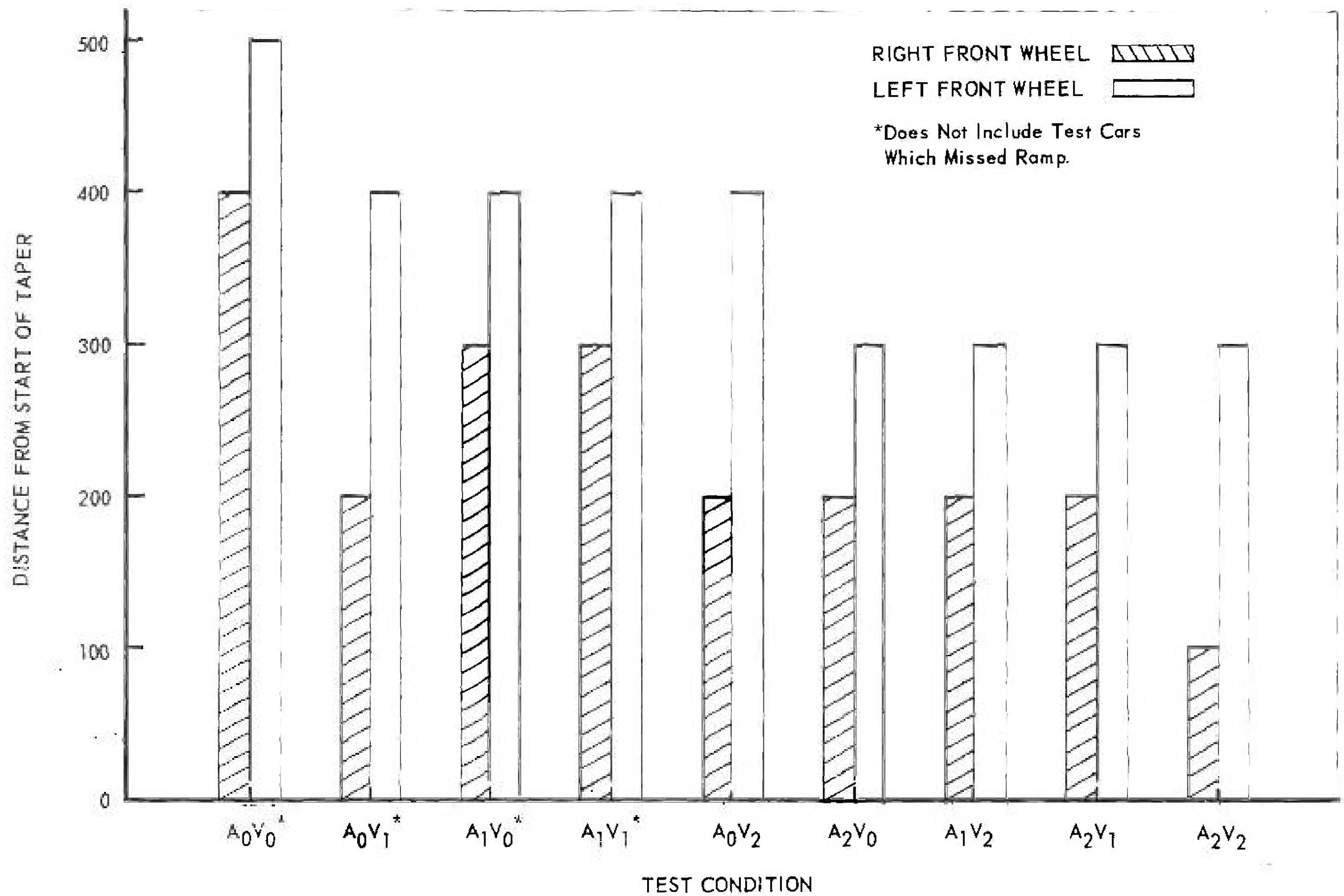


Figure 15. Distance from Point of Taper During Which 50% of Test Cars Entered Deceleration Lane.

CHAPTER V

GENERAL SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Results

The results of the analysis of data are summarized as follows:

1. The analysis of speed data using analysis of variance and multiple range test techniques indicated the following:

(a) In the comparison of all test conditions employed in the experiment it was found that the mean speed over the entire test section of vehicles in test conditions with both advance and exit information and the control group were higher than those in test conditions with only advance information. The only exception to this observation was test condition A_2V_1 which together with test condition A_0V_1 showed different performance by having significantly lower mean speeds than test conditions A_2V_0, A_1V_2, A_2V_2. A_0V_0, and A_0V_2. When the test condition A_2V_1 was run, however, traffic on the freeway was heaviest and as seen in the film analysis many cars drove through the test section in platoons. The probability that most of the test subjects would be under the influence of the general traffic is evidenced by the low speeds recorded during the test condition.

In the vicinity of the advance information point (about 0.5 miles in advance of the exit) vehicle speeds in all test conditions were not significantly different from those in the control group. However, test vehicles in test conditions $A_{(2)}V_1$ and A_0V_1 had significantly lower speeds than those in test condition $A_1V_{(2)}$.

In the vicinity of the exit information point vehicle speeds in test conditions A_2V_1, A_0V_1, A_0V_2 and A_1V_0 were significantly lower than those in the control group, A_0V_0. Also, vehicle speeds in test condition A_0V_1 were significantly lower than those in test conditions A_0V_0, A_2V_2 and A_2V_0, and vehicle speeds in test condition A_2V_1 were significantly lower than those in A_0V_0, A_2V_2, A_2V_0, A_1V_1, A_1V_2 and A_1V_0.

(b) In the comparison of test conditions involving advance information and the control group, vehicle speeds over the entire test section in test condition A_0V_1 were significantly lower than those in test conditions A_0V_0 and A_1V_1.

In the vicinity of the advance information point there were no significant differences between the speeds of vehicles in any of the test conditions and the control group.

In the vicinity of the exit information point, however, vehicles in all test conditions had significantly lower speeds than those in the control group. Vehicles in test condition A_0V_1 had also significantly lower speeds than those in test condition A_1V_1.

(c) In the comparison of test conditions involving both advance and exit information and the control group, vehicle speeds over the entire test section in all test conditions did not differ significantly from each other and the control group except for those in test condition A_2V_1. Vehicle speeds in test condition A_2V_1 were significantly lower than those in all other test conditions and the control group.

In the vicinity of the advance information point vehicle speeds in test condition $A_{(2)}V_1$ were significantly lower than those in test conditions $A_1V_{(2)}$ and $A_{(2)}V_0$.

In the vicinity of the exit information point vehicle speeds in test condition A_2V_1 were found to be significantly lower than those in all other test conditions, and vehicles in test condition A_0V_2 had significantly lower speeds than those in the control group, A_0V_0.

(d) The results of data analysis for vehicle speeds over the entire test section and portions of the test section seemed to indicate that as the amount of information given was increased, vehicles traveled through the test section generally at higher speeds. This is indicated by the higher speeds of vehicles in test conditions with maximum or close to maximum information. This fact was most evidenced in the vicinity of the exit information point where vehicles with less information traveled at lower speeds than vehicles with more information. The low vehicle speeds in test conditions with less information may be regarded as an indication of uncertainty of the driver with regard to the location of the exit ramp.

Similarly, vehicles in the control group, A_0V_0, had speeds comparable to those in test conditions with substantial information. Vehicles in the control group were not given any information at all along the test section and were not expecting to exit at the end of the test section. These vehicles drove normally along the test section and no uncertainty was involved as to the location of the exit ramp at the end of the test section.

(e) Vehicle speeds in test conditions A_1V_0 and A_2V_0 (all radio) were not significantly different from those in test conditions A_0V_1 and A_0V_2 (all signs) respectively. However, in the vicinity of the exit vehicle speeds in test conditions A_0V_1 and A_0V_2 were significantly lower than those in test conditions A_1V_1 and A_0V_0 respectively. The respective vehicle speeds in test conditions A_1V_0 and A_2V_0 were not significantly different from those in test conditions A_1V_1 and A_0V_0.

(f) Other comparisons of mean speeds at speed measurement positions showed that there were significant differences between some of the positions where information was being given and various other positions where no information was being given. Although no definite conclusions could be derived as to which test conditions caused these significant differences, it was evident that these differences were due to the fact that some sort of information was given.

2. The analysis of rates of acceleration indicated the following:

(a) The mean acceleration rates of vehicles in the various test conditions employed in the experiment did not differ significantly from those of the control group. However, vehicles in test condition A_0V_2 showed a poor performance by having high rates of deceleration along the test section as compared to those in test conditions A_2V_2 and A_1V_2.

(b) Vehicles in test conditions with audio messages and with visual messages supplemented by audio messages had rates of acceleration or deceleration closer to zero along the test section than those in test conditions with only visual messages.

(c) In the vicinity of the advance information point there were no indications as to which test condition produced better driving performance.

(d) In the vicinity of the exit information point, all test conditions employed in the experiment had different rates of deceleration but no significant differences could be found.

(e) Various comparisons of rates of acceleration in acceleration zones indicated that test vehicles decelerated after advance or exit information was given.

(f) Vehicle acceleration rates in the various test conditions compared with respect to each individual acceleration zone indicated that there were significant differences in zones 4, 5 and 8. It is interesting to note that advance information was being given in zones 4 and 5 while exit information was being given in zone 8.

3. The analysis of acceleration noise data indicated a significant difference between the values of acceleration noise in test condition A_0V_2 and those in test conditions A_2V_2, A_0V_1, A_2V_1 and A_2V_0. The latter four test conditions had lower values and closer to zero than all others. These data indicate that generally test conditions including two audio messages had more favorable values of acceleration noise than other test conditions.

4. Travel times of test subjects participating in the experiment did not differ significantly no matter what test condition was employed.

5. The results of the analysis of the point of entry data are as follows:

(a) Exit information given only in the vicinity of the advance information point was found to be an inadequate amount of information. Even when both audio and visual advance information was given there were test cars missing the exit ramp.

(b) As the amount of information given about an exit ramp was increased, the entry of test cars into the deceleration lane was closer to the beginning of the tapered section of the deceleration lane.

(c) Fifty-seven per cent of the test subjects in test condition A_2V_2 entered the deceleration lane within the first 100 feet from beginning of the tapered section of the deceleration lane. For test subjects participating in test conditions A_2V_1, A_1V_2, A_2V_0 and A_0V_2 the corresponding values were 40%, 42%, 30%, and 23%, respectively.

(d) Sixty-nine per cent of the test subjects participating in the control group, A_0V_0, where the only information given was an exit sign at the gore of the exit ramp missed the exit ramp. Furthermore, no test car entered the deceleration lane within 100 feet from the beginning of the tapered section of the deceleration lane.

Conclusions

1. The results of data analysis seemed to indicate that the provision of roadside radio communication in addition to standard highway signing may be useful to drivers. This fact was evidenced in the better performance of test subjects in the test conditions where the amount of information given was maximum or close to maximum.

2. Audio messages seemed to be as effective as visual messages. This fact was indicated by the non-significant differences in speeds and rates of acceleration between test conditions A_1V_0 and A_2V_0, and test conditions A_0V_1 and A_0V_2 respectively. However, vehicles in test conditions with only audio messages had higher speeds than those in test conditions with only visual messages. Also, test condition A_2V_0 had a more

favorable value of acceleration noise than test condition A_0V_2.

3. When only advance information was provided there was not enough evidence as to which test condition produced better driving performance with respect to vehicle speeds and accelerations.

4. Giving advance guidance information only about the location of an exit ramp was found to be inadequate in the performance of a diverging maneuver from the freeway. This inadequacy was evidenced by the number of test subjects missing the ramp when only advance information was given.

5. When the information given about an exit ramp consisted of both advance and exit information no test subject missed the ramp and as the amount of information was increased the entry into the deceleration lane was made earlier than otherwise.

Recommendations

The results of this experiment gave a general idea about the effectiveness of roadside radio communication as a traffic control and driver information device. In evaluating the results obtained from the study, however, consideration should be given to the fact that highly motivated test subjects were used in the experiment. In addition, the number of test subjects in each test condition was reduced considerably due to equipment deficiencies and the effect of the leading and trailing cars on the speed of the test cars.

The results of data analysis indicated that audio messages seemed to be as effective as visual messages and could be used when highway signs seem infeasible. Also, audio messages seemed to be very effective in supplementing visual messages. When both audio and visual messages were provided to test drivers, their performance has proven to be generally better than the performance of test drivers in other test conditions. A Radio-Signing system which will provide the necessary information where needed could be effective and at the same time avoid extensive over-signing.

Further research should be conducted on a system basis to investigate the use of radio as a communication system to provide traffic control and driver information and to conclusively determine specific areas of feasibility of roadside radio communication.

APPENDICES

APPENDIX A

Information Given to Test Subjects

INFORMATION GIVEN TO THOSE INTERESTED IN TRAFFIC PROBLEMS

Georgia Institute of Technology
Atlanta, Georgia 30332

Return to:
Dr. Donald O. Covault
School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia
June, 1965

To: Those who are interested in traffic problems
From: Dr. Donald O. Covault

As you may know, Georgia Tech conducted experiments last summer on the Atlanta Freeway to evaluate the effectiveness of roadside radio communication on traffic control and driver behavior. These experiments were successfully concluded in August, 1964 and a summary of the findings is attached for your information. Also attached is a general description of how the radio communication system works.

We are planning to conduct another series of experiments this year on the Downtown Connector and the East Freeway sometime from the middle to the end of July. The experiments will be conducted during the night-time hours. Georgia Tech would like to loan to you a special radio receiver and observe your reactions to radio communications on this selected section of the Atlanta Freeway. To perform each experiment will require approximately one-half hour of your time. You will be asked to participate approximately three times in the entire series of experiments. The time period for the experiments will be from 8:30 to 11:00 PM in the evening. These experiments will be distributed through a two-week period.

If you wish to participate in the experiments to be conducted this year, please fill out the attached questionnaire and return to the address listed above.

Sincerely yours,

Donald O. Covault
Project Director

- - - - - - - - - - - - - -

1. Did you participate in this experiment last year? Yes No
2. Would you be willing to participate in the radio communication experiments proposed for this year? Yes No

Name ______________________________
Address ______________________________
Phone (Business)______________ (Home)____________

GENERAL DESCRIPTION OF ROADSIDE RADIO COMMUNICATION

A new method of driver-roadside communication has been the subject of a research project conducted by the Engineering Experiment Station of the Georgia Institute of Technology under the sponsorship of the Bureau of Public Roads. The communication system called Hy-Com was developed by the Delco Radio Division of General Motors Company. Hy-Com consists of a car-mounted receiver (see Figure 1) and a roadside transmitter (see Figure 2). The receiver is mounted on the trunk lid of the automobile with three circular magnets covered with phenolic discs to protect the car's finish. The transmitter is placed beside the highway with its two antennae loops (see Figure 3). As an automobile approaches the trigger antenna a trigger circuit in the receiver is activated energizing the audio stages of the receiver, which allows the driver to hear the message transmitted by the information antenna.

In 1963 a series of experiments were conducted on the Kentucky Toll Road just south of Louisville and in 1964 on a section of the Northwest Freeway in Atlanta, Georgia. This summer a series of experiments is planned for the Downtown Connector and a section of the East Freeway in Atlanta.

This information is being sent to you in the hope that you would like to participate in these experiments. Please complete the enclosed questionnaire if you would be interested in participating in the experiments planned for this summer.

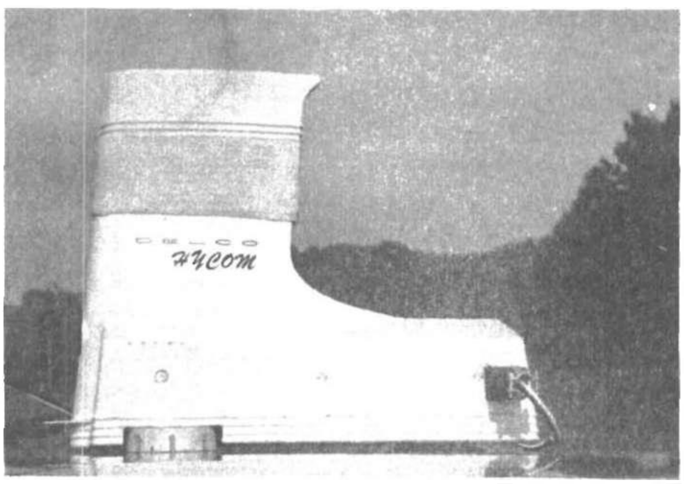


Figure 1. Receiver Mounted on an Automobile Trunk Lid.

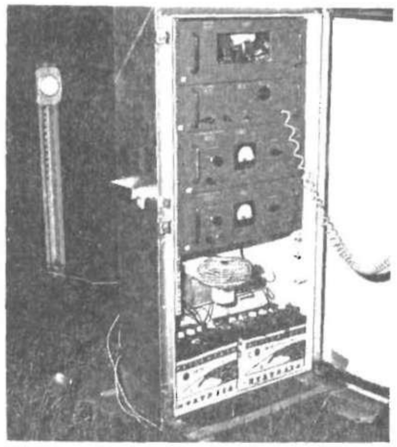


Figure 2. Inside View of a Transmitter Cabinet.

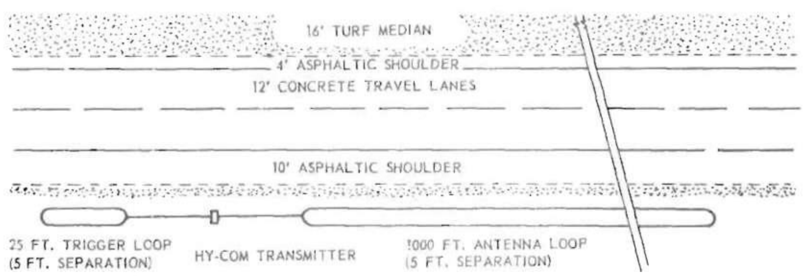


Figure 3. Antenna Loop Layout.

SUMMARY OF ROADSIDE RADIO COMMUNICATION EXPERIMENTS
PERFORMED IN JULY, 1964 ON THE NORTHWEST FREEWAY

The feasibility of using a roadside radio communication system for traffic control and driver information was investigated on a four-mile section of the Northwest Freeway in Atlanta, Georgia, in July 1964. The purpose of this research was to evaluate the effectiveness of the roadside radio communication system on the decision making process of the driver as related to his execution of a traffic maneuver, such as a diverging maneuver from a freeway traffic stream. To accomplish the stated objectives an experiment was designed involving a series of individual tests. For the experiment several different test conditions were developed, each with different combinations of visual and audio guidance information to be provided at a specific freeway exit ramp.

A total number of 127 volunteer participants participated in the experiments. To negate as much as possible the test subject's specific advance knowledge regarding the exact location and characteristics of the freeway exit at the interchange, selected for the purpose of the experiment, this interchange was renamed "Random Road."

Highway information signs, carrying the "Random Road" legend and approaching within practical limits freeway signing standards, were employed to provide visual information. The radio equipment used to provide audio messages to the drivers was developed by Delco Radio Division of General Motors Company. This induction radio system, called "Hy-Com," consists of a car mounted receiver and roadside transmitter.

Analysis of variance and multiple comparison tests were performed on the data collected. The results of the analysis led to the following conclusions:

1. The provision of roadside radio communication in addition to standard advance highway signing did not significantly affect the speed at which motorists traveled at a point approximately one half mile in advance of the exit terminal as compared to vehicle speeds of motorists traveling under conditions of standard advance highway signing only.

2. When the guidance information consisted of both advance and exit information, in general, the manner in which the motorists operated their vehicles did not significantly differ in neither vehicle speeds nor rates of deceleration along the deceleration lane.

3. When the guidance information consisted of the standard advance highway sign only, motorists traveled at significantly lower speeds throughout the length of deceleration area than motorists traveling under conditions of standard advance and exit signing supplemented with advance and exit audio messages.

4. Roadside radio communication was indicated to be an effective device in warning motorists of potential hazards along the highway as evidenced by significantly different vehicle speeds between test and control drivers during the grass cutting experiment.

5. There was some indication that the amount of information given to a driver, either by sign or radio, influenced the manner in which a diverging maneuver was made at the off-ramp at "Random Road."

INFORMATION GIVEN TO TEST SUBJECTS PARTICIPATING IN THE EXPERIMENT

Dr. Donald O. Covault
School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia
July 15, 1965

Dear Participant:

Many people complain about traffic problems but few have the opportunity to do anything about them. By volunteering for the radio communication traffic research project you have indicated your willingness to take the opportunity of doing something.

In order to fully acquaint you with the project I would like to ask you to attend a briefing session at the Electrical Engineering Auditorium at Georgia Tech on either Thursday, July 15th; Friday, July 16th; or Saturday, July 17th at one of the times listed below. Because you will be assigned to a specific test group it is important that you attend this briefing session. The total time required for this briefing should not exceed one-half of an hour.

	Thursday July 15	Friday July 16	Saturday July 17
Briefing Session Times	8:00 AM	8:00 AM	10:00 AM
	12:00 Noon	12:00 Noon	
	4:00 PM	4:00 PM	
	8:00 PM	8:00 PM	

A map showing the location of the Electrical Engineering Building Auditorium is enclosed for those persons who are not familiar with the Georgia Tech Campus. Space for parking is available on the campus adjacent to the building.

Enclosed is explanatory material regarding the experiment.

Thanking you again for your help and cooperation, I am

Most sincerely yours,

Donald O. Covault
Project Director

P.S. Additional participants can be used in the experiments. If you know of anyone who may be interested in participating as a test driver, bring him along with you when you come to the briefing session.

Enclosure

GEORGIA INSTITUTE OF TECHNOLOGY
Radio Communication Experiment

For information call:
Traffic Experiment 873-4211, Ext. 634

Thank you for volunteering to participate in the experiment.

The project in which you have volunteered to assist is designed to evaluate the use of radio communications for traffic control and driver information as compared to conventional highway signing. The following is a description of the equipment and how the experiment is to be conducted:

Radio Equipment

The system of radio communication used in this experiment was developed by Delco Radio, a division of General Motors. The system is designed to provide communications from the roadside to the driver and consists of a car mounted receiver and roadside transmitter.

The receiver is encased in a plastic case and has three circular magnets which hold the unit in place on the trunk lid of your car. The magnets are covered with phenolic discs to protect the automobile finish. For most passenger cars a rubber coated safety hook is placed in the crack between the trunk lid and the body of the automobile. Receivers for station wagons and other types of cars can be mounted also without difficulty. The speaker is cable connected to the receiver and can be mounted on the sunvisor or body trim of the car with a spring clip.

The transmitter unit consists of a message repeater, trigger and information transmitter, and two loop antennae. The system is a single side band, suppressed one-way communications link and broadcasts signals at 12.1 K.C.

Equipment Operation

No manual manipulation of the equipment by the driver is required.

As the receiver on an approaching automobile enters the induction field of the trigger loop antenna which is positioned on the highway shoulder just prior to the transmitter, a trigger circuit in the receiver is activated which energizes the audio stages of the receiver. A time delay holds the audio section in the "on" position to permit the automobile to reach the information antenna which is positioned just beyond the transmitter. As the receiver enters the field of the information antenna it senses the information signal and provides an audible message to the driver. Figure 1 is a sketch of a transmitter and antenna positioned along the roadside.

Trip Schedule

You are asked to make one trip through the test section. Each participant will be assigned to one of the several groups. The group assignment will be made at the briefing sessions to be held on Thursday, July 15, Friday, July 16, and Saturday, July 17.

In the event of wet pavement during the night of the experiment, the test runs scheduled for that night will be cancelled and rescheduled. Telephone contact will be made with each participant to notify him of the time of the experiment and of cancellations and rescheduling.

Staging Area, Test Run, Equipment Recovery

On the night you are scheduled to participate and any time between 8:30 PM and 11:00 PM you are asked to report at the "staging area" on Fowler Street at the Colosseum near 10th Street on the Georgia Tech campus. At this point the project personnel will install a special radio receiver and speaker on your car and identify your car with a light and bumper sticker. The equipment will require only a few minutes for installation and will not damage the finish of your automobile. The light and the bumper sticker will be removed at the end of the experiment and will not leave any residue on your car.

With the radio equipment and identification light and sticker installed, you are requested to drive the following route:

1. From the staging area on Fowler onto 10th Street to the Freeway Southbound.

2. Then South on the Freeway through the Downtown Connector to I-20 (East Freeway).

3. Exit the East Freeway at Glenwood interchange and turn around onto the East Freeway and travel in the westbound direction toward Atlanta.

4. Exit the East Freeway at the "Random Road" interchange and return to the staging area on Fowler Street at the Colosseum where the radio equipment and identification light and sticker will be removed.

5. In the event you cannot find the "Random Road" proceed to the Downtown Connector and return to the "staging area" on Fowler Street at the Colosseum on the Georgia Tech Campus.

Figure 2 is a sketch of the staging area and the test route.

One of the existing interchanges on the East Freeway has been renamed "Random Road" and is signed as such in the conventional manner, except that the sign legend will consist of white lettering on a black background, as compared with the standard white lettering on a green background.

On the Freeway between Georgia Tech and the "Random Road" exit on the East Freeway you will receive radio messages concerning actual roadway conditions. Please react normally in your driving after hearing these messages.

Upon your return at the staging area on Fowler Street the radio receiver and speaker and the identification sticker and light will be removed from your car.

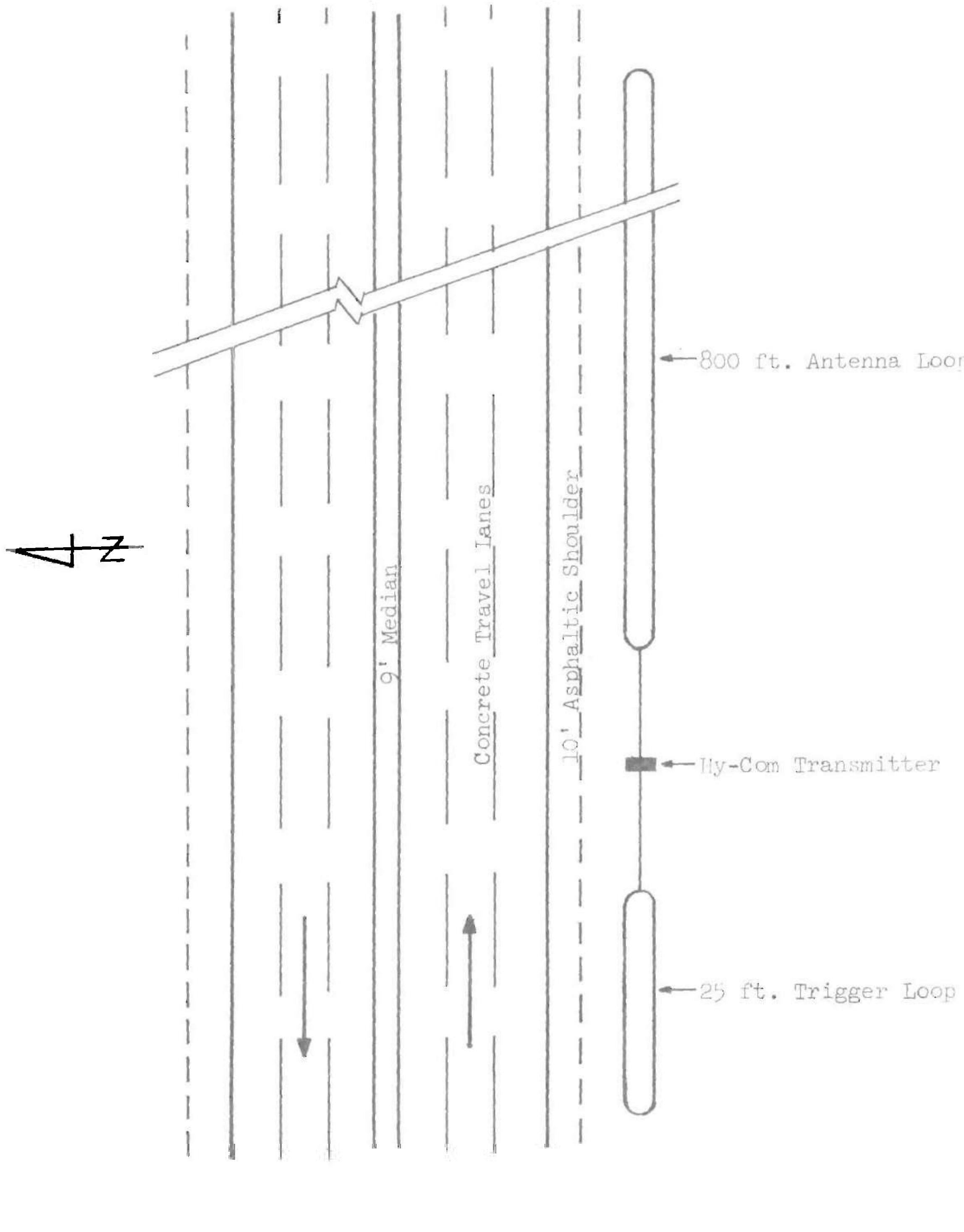


Figure 1. Typical Transmitter and Loop Installation

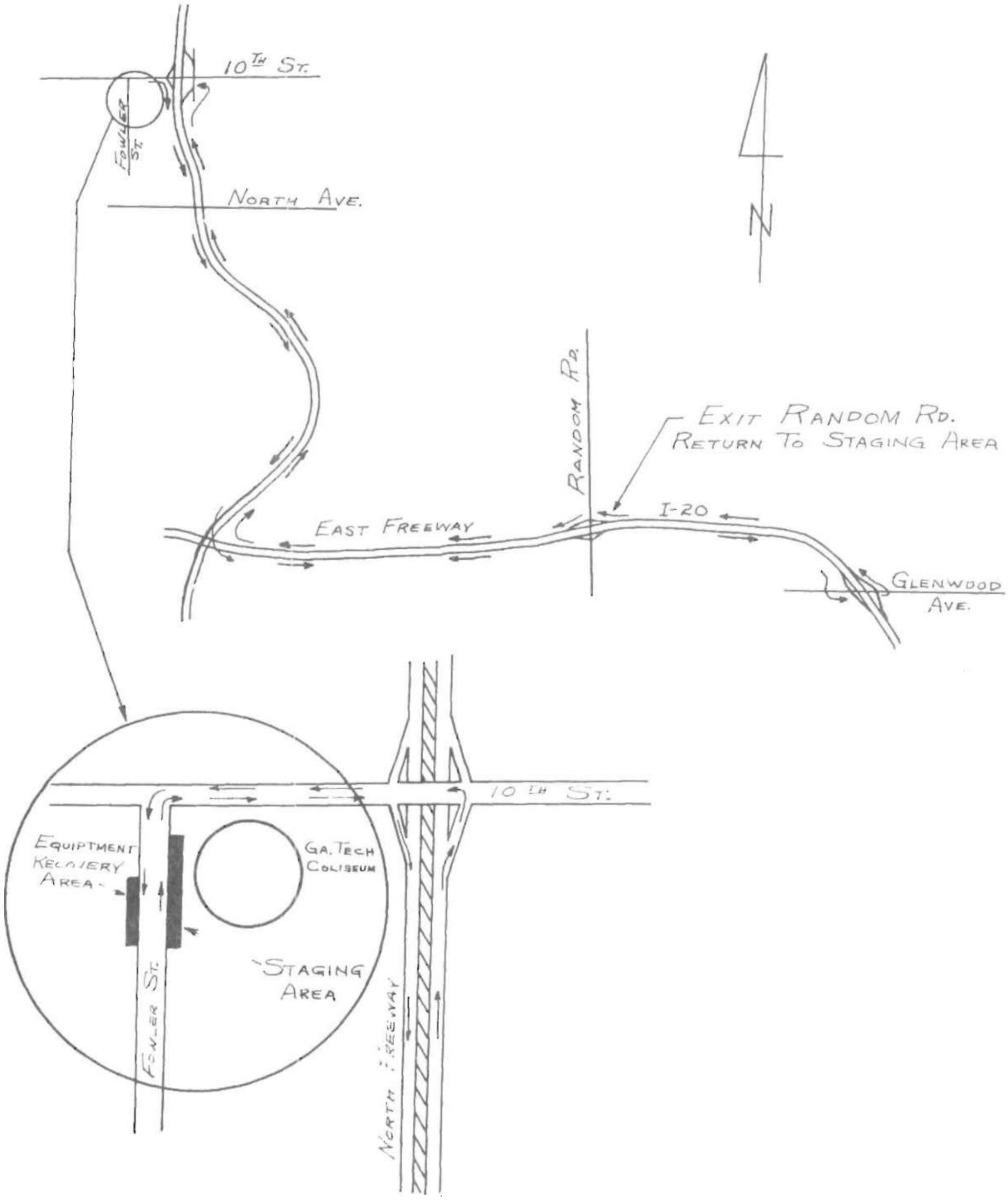


Figure 2. Location Sketch of the Staging Area, Test Route, and Equipment Recovery Area.

LIST OF MESSAGES GIVEN TO TEST SUBJECTS
IN VARIOUS TEST CONDITIONS

RADIO COMMUNICATION AND TRAFFIC CONTROL EXPERIMENT

Dr. Donald O. Covault
School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia
August 15, 1965

Dear Test Participant:

On behalf of myself and the entire test personnel, I would like to take this opportunity to extend to you our thanks and appreciation for so generously volunteering your time and interest toward making our traffic test a success. We certainly hope you had no difficulty discovering "Random Road" and that you found your part in the experiment both enjoyable and informative. As you may have discovered, "Random Road" is actually Hill Street in real life.

In order that you might see more clearly just what your contribution may have been, the attached tables show a general summary of the test plan employed during the experiment. Your test group is underlined in red on the attached sheet.

Did you find your group? The table indicates exactly what radio and sign messages you should have received.

I should insert a word here for the control group (test 9), because some type of explanation seems to be in order. As you perhaps know, one of the main purposes of this series of experiments was to determine exactly how much information it is necessary to communicate to the driver to clarify the message with the least possible redundancy, and exactly how this information should be given (radio or signs). The persons in the control group received very little information regarding the location of "Random Road," while other test groups received more than sufficient information to locate the exit.

We are now starting to analyze the multitude of data which was collected. A summary of this information will be sent to you about next Spring after the complete analysis is made.

Once again, I want you to know how grateful we are for your interest and cooperation in volunteering for these experiments. Everyone is willing to complain about the traffic problems. Fortunately you are one of those persons who is interested in trying to help solve these problems.

Most sincerely yours,

Donald O. Covault
Project Director

RADIO COMMUNICATIONS EXPERIMENT

List of Messages Given to Various Test Groups

Test Group	Date	Location	Audio Messages (radio)	Visual Messages (sign)
1	July 19, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	No message or Random Road Exit 1/2 mile	Random Road Exit 1/2 mile or no message
		Hill Street	no message	Exit ↗
2	July 20, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	Random Road Exit 1/2 mile or no message	no message or Random Road Exit 1/2 mile
		Hill Street	no message	Exit ↗

Test Group	Date	Location	Audio Messages (radio)	Visual Messages (sign)
3	July 21, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	no message	Random Road Exit 1/2 mile
		Hill Street	no message	Random Road ↗ Exit ↗
4	July 22, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	Random Road Exit 1/2 mile	Random Road Exit 1/2 mile
		Hill Street	no message	Exit ↗

Test Group	Date	Location	Audio Messages (radio)	Visual Messages (sign)
5	July 23, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	Random Road Exit 1/2 mile	Random Road Exit 1/2 mile
		Hill Street	Random Road Exit	Exit ↗
6	July 26, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	Random Road Exit 1/2 mile	Random Road Exit 1/2 mile
		Hill Street	Random Road Exit	Random Road ↗ Exit ↗

Test Group	Date	Location	Audio Messages (radio)	Visual Messages (sign)
7	July [illegible], 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	Random Road Exit 1/2 mile	no message
		Hill Street	Random Road Exit	Exit ↗
9	July 30, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	no message	no message
		Hill Street	no message	Exit ↗

Test Group	Date	Location	Audio Messages (radio)	Visual Messages (sign)
10	August 2, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	no message	Random Road Exit 1/2 mile
		Hill Street	no message	Random Road ↗ Exit ↗
8	August 3, 1965	Staging Area	Actual Highway Conditions will be given to you on the Atlanta Freeway	No message concerning the location of Random Road
		Near Glenwood at Glenwood off-ramp	Turn around at Glenwood	Random Road ←
		East of Moreland Ave.	Use right traffic lane	no message
		Boulevard	Random Road Exit 1/2 mile	Random Road Exit 1/2 mile
		Hill Street	no message	Random Road ↗ Exit ↗

APPENDIX B

Test Conditions and Test Subjects

Table B-1. Schedule of Test Conditions

Date	Test condition no.	Level of information	No. of participants
July 19, 1965	1	A_0V_1	19
	2	A_1V_0	19
July 20, 1965	1	A_0V_1	4
	2	A_1V_0	26
July 21, 1965	3	A_0V_2*	33
July 22, 1965	4	A_1V_1	33
July 23, 1965	5	A_2V_1	38
July 26, 1965	6	A_2V_2	31
July 27, 1965	7	A_2V_0	33
July 28, 1965	8	A_1V_2**	-
July 30, 1965	9	A_0V_0	26
August 2, 1965	10 (3)	A_0V_2	22
August 3, 1965	11 (8)	A_1V_2	26

*Test run was repeated as 10 (3), using different test subjects because of an accident on the test section.

**Test run rescheduled as 11 (8) because of rain.

Note: The time period for each test condition was from 8:30 p.m. to 11:00 p.m.

Table B-2. Test Subjects In Each Test Condition

Test Condition	Vicinity of Advance Information Point: No. Partici-pating	Vicinity of Advance Information Point: No. Used in Analysis	Vicinity of Exit Information Point: No. Partici-pating	Vicinity of Exit Information Point: No. Used in Analysis	Entire Test Section: No. Partici-pating	Entire Test Section: No. Used in Analysis
	No. of Test Subjects Participating and the Actual No. that could be Used in Analysis					
A_0V_0	26	14	26	18	26	12
A_0V_1	23	12	23	16	23	11
A_1V_0	45	13	45	12	45	11
A_0V_2*	33	9	33	7	33	6
	22	8	22	10	22	6
A_2V_0	33	17	33	20	33	16
A_1V_1	33	20	33	18	33	17
A_1V_2	26	13	26	13	26	12
A_2V_1	38	21	38	19	38	16
A_2V_2	31	14	31	14	31	14
Total No.	310	141	310	147	310	121

*Test condition repeated using different test subjects because of an accident on the test section.

APPENDIX C

Mean Vehicle Speeds and Mean Rates of Acceleration

Table C-1. Mean Vehicle Speeds in Miles per hour of the Test and Control Group at Each Speed Measurement Position in the Vicinity of Advance Information Point

Speed Position	Test Condition								
	A_0V_0	A_0V_1	A_1V_0	A_1V_1	A_0V_2	A_2V_0	A_1V_2	A_2V_1	A_2V_2
1	48.14	46.42	48.62	48.45	49.24	51.12	49.85	48.38	49.14
2	46.29	44.25	44.62	44.95	47.59	47.65	46.46	44.95	46.36
3	47.71	44.17	46.00	46.55	47.41	48.00	49.54	46.10	47.64
4	48.50	46.83	49.00	48.70	48.53	48.12	49.55	47.76	47.28
5	47.57	46.25	49.54	47.35	46.35	48.59	51.54	46.14	49.00
6	51.79	50.16	52.08	49.90	51.82	51.88	52.54	46.71	50.86

Table C-2. Mean Vehicle Speeds in Miles per hour of the Test and Control Group at Each Speed Measurement Position in the Vicinity of Exit Information Point

Speed Position	Test Condition								
	A_0V_0	A_0V_1	A_1V_0	A_1V_1	A_0V_2	A_2V_0	A_1V_2	A_2V_1	A_2V_2
6	53.22	48.69	51.00	49.72	46.71	51.40	52.46	45.95	50.86
7	54.61	46.38	49.75	50.61	48.76	52.00	50.69	45.74	51.57
8	50.44	45.25	47.62	48.56	49.06	49.75	49.00	43.95	49.14
9	50.56	44.69	47.33	48.83	47.65	49.85	48.08	44.53	49.36
10	51.22	44.93	47.08	48.83	47.00	48.60	47.08	44.37	49.43
11	49.16	43.93	45.50	46.54	45.35	46.80	46.00	43.05	48.14

Table C-3. Mean Vehicle Speeds in Miles per hour of the Test and Control Groups at Each Speed Measurement Position in the Entire Test Section

Speed Position	Test Condition								
	A_0V_0	A_0V_1	A_1V_0	A_1V_1	A_0V_2	A_2V_0	A_1V_2	A_2V_1	A_2V_2
1	47.67	45.73	47.82	48.00	49.33	50.69	50.17	47.56	49.14
2	45.75	43.45	43.82	44.47	47.83	47.31	47.08	44.00	46.36
3	47.42	43.36	45.55	46.29	47.17	47.50	49.75	45.00	47.64
4	48.33	46.27	48.27	48.24	49.08	48.19	50.83	46.88	47.29
5	47.42	45.36	48.73	46.88	47.17	48.75	51.92	45.75	49.00
6	51.92	49.64	51.36	49.59	49.92	52.12	52.25	46.63	50.86
7	52.42	47.00	49.73	50.35	49.58	52.75	51.50	46.69	51.57
8	48.67	45.18	47.55	48.18	50.75	50.25	49.25	44.69	49.14
9	49.00	44.64	47.27	48.41	48.33	50.25	48.25	45.44	49.36
10	49.92	44.91	47.09	48.47	47.17	48.88	47.17	44.94	49.43
11	47.67	44.00	45.45	46.71	45.50	47.12	46.17	43.50	48.14

Table C-4. Rank Order and Significant Differences Between Mean Speed in MPH of Test Conditions at the Various Speed Positions

Position	Test Condition								
1*	A_2V_0	A_1V_2	A_0V_2	A_2V_2	A_1V_1	A_1V_0	A_0V_0	A_2V_1	A_0V_1
	50.69	50.17	49.33	49.14	48.00	47.82	47.67	47.56	45.73
2	$A_0V_{(2)}$	$A_{(2)}V_0$	$A_1V_{(2)}$	$A_{(2)}V_{(2)}$	A_0V_0	A_1V_1	$A_{(2)}V_1$	A_1V_0	A_0V_1
	47.83	47.31	47.08	46.36	45.75	44.77	44.00	43.82	43.45
3	$A_1V_{(2)}$	$A_{(2)}V_{(2)}$	$A_{(2)}V_0$	A_0V_0	$A_0V_{(2)}$	A_1V_1	A_1V_0	$A_{(2)}V_1$	A_0V_1
	49.75	47.64	47.50	47.42	47.17	46.29	45.55	45.00	43.36
4	$A_1V_{(2)}$	$A_0V_{(2)}$	A_0V_0	A_1V_0	A_1V_1	$A_{(2)}V_0$	$A_{(2)}V_{(2)}$	$A_{(2)}V_1$	A_0V_1
	50.83	49.08	48.33	48.27	48.24	48.19	47.29	46.88	46.27
5	$A_1V_{(2)}$	$A_{(2)}V_{(2)}$	$A_{(2)}V_0$	A_1V_0	A_0V_0	$A_0V_{(2)}$	A_1V_1	$A_{(2)}V_1$	A_0V_1
	51.92	49.00	48.75	48.73	47.42	47.17	46.88	45.75	45.36
6	$A_1V_{(2)}$	$A_{(2)}V_0$	A_0V_0	A_1V_0	$A_{(2)}V_{(2)}$	$A_0V_{(2)}$	A_0V_1	A_1V_1	$A_{(2)}V_1$
	52.25	52.12	51.92	51.36	50.86	49.92	49.64	49.59	46.63
7	$A_{(2)}V_0$	A_0V_0	$A_{(2)}V_{(2)}$	$A_1V_{(2)}$	A_1V_1	A_1V_0	$A_0V_{(2)}$	A_0V_1	$A_{(2)}V_1$
	52.75	52.42	51.57	51.50	50.35	49.73	49.58	47.00	46.69
8	A_0V_2	A_2V_0	A_1V_2	A_2V_2	A_0V_0	A_1V_1	A_1V_0	A_0V_1	A_2V_1
	50.75	50.25	49.25	49.14	48.67	48.18	47.55	45.18	44.69
9	A_2V_0	A_2V_2	A_0V_0	A_1V_1	A_0V_2	A_1V_2	A_1V_0	A_2V_1	A_0V_1
	50.25	49.36	49.00	48.41	48.33	48.25	47.27	45.44	44.64

*At Position 1 no information was given to any test condition employed in the experiment.

Table C-4. (Continued)

Position	Test Condition								
10	A_0V_0	A_2V_2	A_2V_0	A_1V_1	A_1V_2	A_0V_2	A_1V_0	A_2V_1	A_0V_1
	49.92	49.43	48.88	48.47	47.17	47.17	47.09	44.94	44.91
11	A_2V_2	A_0V_0	A_2V_0	A_1V_1	A_1V_2	A_0V_2	A_1V_0	A_0V_1	A_2V_1
	48.14	47.67	47.12	46.71	46.17	45.50	45.45	44.00	43.50

Table C-5. Mean Vehicle Rates of Acceleration in Ft/Sec^2 of the Test and Control Groups in Each Zone in the Vicinity of Advance Information Point

Acceleration Zone	A_0V_0	A_0V_1	A_1V_0	A_1V_1	A_0V_2	A_2V_0	A_1V_2	A_2V_1	A_2V_2
1	-0.413	-0.459	-0.880	-0.748	-0.419	-0.736	-0.804	-0.796	-0.616
2	0.861	0.058	0.792	0.846	-0.098	0.277	1.812	0.715	0.874
3	0.279	0.875	1.001	0.751	0.426	0.014	0.426	0.501	-0.190
4	-1.576	-0.958	0.688	-2.093	-2.570	0.641	1.461	-2.079	2.270
5	1.138	1.000	0.642	0.679	0.639	0.850	0.313	0.152	0.451

Table C-6. Mean Vehicle Rates of Acceleration in Ft/Sec^2 of the Test and Control Groups in Each Zone in the Vicinity of Advance Information Point

Acceleration Zone	A_0V_0	A_0V_1	A_1V_0	A_1V_1	A_0V_2	A_2V_0	A_1V_2	A_2V_1	A_2V_2
6	0.140	-0.193	-0.054	0.083	-0.055	0.063	-0.173	0.008	0.058
7	-1.434	-0.327	-0.639	-0.666	0.181	-0.738	0.630	-0.474	-0.801
8	0.094	-0.631	-0.351	0.359	-1.943	0.072	-0.978	0.579	0.242
9	0.223	0.034	-0.065	-0.004	-0.235	-0.416	0.327	-0.052	0.028
10	-2.318	-0.964	-1.613	-2.069	-1.668	-1.901	-1.089	-1.178	-1.387

Table C-7. Mean Vehicle Rates of Acceleration in Ft/Sec^2 of the Test and Control Groups in Each Zone in the Entire Test Section.

Acceleration Zone	Test Condition								
	A_0V_0	A_0V_1	A_1V_0	A_1V_1	A_0V_2	A_2V_0	A_1V_2	A_2V_1	A_2V_2
1	-0.420	-0.501	-0.792	-0.749	-0.409	-0.697	-0.749	-0.809	-0.616
2	0.995	0.064	0.991	0.980	-0.373	0.157	1.578	0.585	0.874
3	0.326	0.955	0.896	0.676	0.720	0.223	0.462	0.556	-0.190
4	-1.606	-1.445	0.551	-1.923	-2.309	0.759	1.583	-1.397	2.270
5	1.213	1.091	0.656	0.692	0.658	0.873	0.141	0.228	0.451
6	0.042	-0.219	-0.084	0.070	-0.096	0.067	-0.125	0.086	0.058
7	-1.236	-0.534	-0.671	-0.702	0.409	-0.826	-0.657	-0.523	-0.801
8	0.364	-0.663	-0.289	0.310	-3.134	-0.032	-1.059	0.749	0.242
9	0.299	0.027	-0.043	0.018	-0.375	-0.463	0.354	-0.141	0.028
10	-2.480	-0.878	-1.668	-1.922	-1.666	-1.885	-1.018	-1.288	-1.387

Table C-8. Rank Order and Significant Differences Between Rates of Acceleration in Ft/Sec^2 of Test Conditions at the Various Acceleration Zones

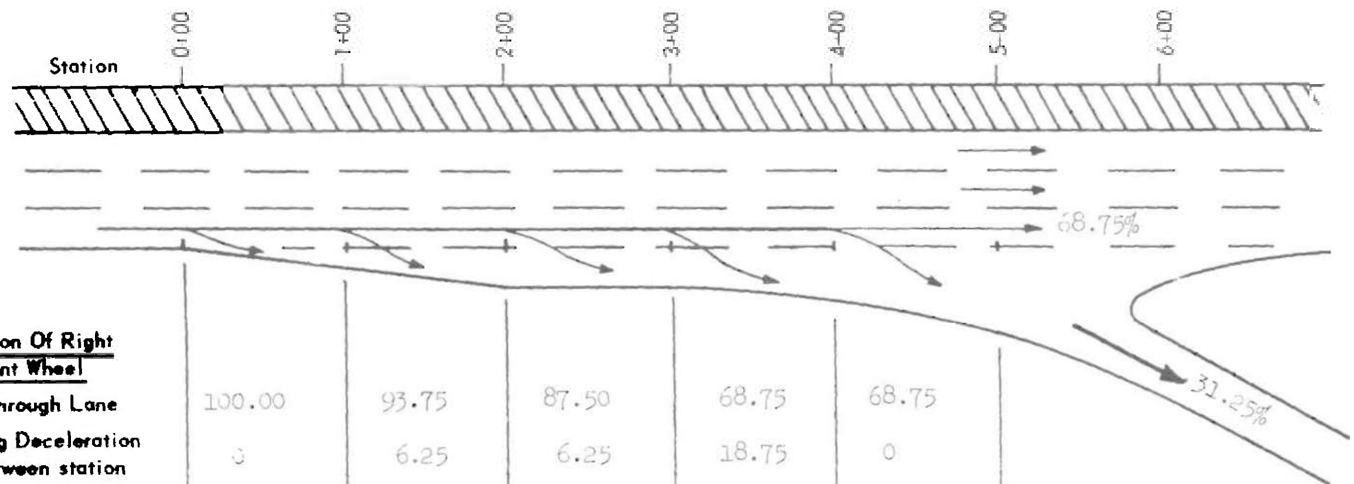
Zone	Test Condition and Mean Acceleration in Zone								
1	$A_0V_{(2)}$	A_0V_0	A_0V_1	$A_{(2)}V_{(2)}$	$A_{(2)}V_0$	A_1V_1	$A_1V_{(2)}$	A_1V_0	$A_{(2)}V_1$
	-0.409	-0.420	-0.501	-0.616	-0.697	-0.749	-0.749	-0.792	-0.809
2	$A_1V_{(2)}$	A_0V_0	A_1V_0	A_1V_1	$A_{(2)}V_{(2)}$	$A_{(2)}V_1$	$A_{(2)}V_0$	A_0V_1	$A_0V_{(2)}$
	1.578	0.995	0.991	0.980	0.874	0.585	0.157	0.064	-0.373
3	A_0V_1	A_1V_0	$A_0V_{(2)}$	A_1V_1	$A_{(2)}V_1$	$A_1V_{(2)}$	A_0V_0	$A_{(2)}V_0$	$A_{(2)}V_{(2)}$
	0.955	0.896	0.720	0.676	0.556	0.462	0.326	0.223	-0.190
4	$A_{(2)}V_{(2)}$	$A_1V_{(2)}$	$A_{(2)}V_0$	A_1V_0	$A_{(2)}V_1$	A_0V_1	A_0V_0	A_1V_1	$A_0V_{(2)}$
	2.270	1.583	0.759	0.551	-1.397	-1.445	-1.606	-1.923	-2.309
5	A_0V_0	A_0V_1	$A_{(2)}V_0$	A_1V_1	$A_0V_{(2)}$	A_1V_0	$A_{(2)}V_{(2)}$	$A_{(2)}V_1$	$A_1V_{(2)}$
	1.213	1.091	0.873	0.692	0.658	0.656	0.451	0.228	0.141
6	$A_{(2)}V_1$	A_1V_1	$A_{(2)}V_0$	$A_{(2)}V_{(2)}$	A_0V_0	A_1V_0	$A_0V_{(2)}$	$A_1V_{(2)}$	A_0V_1
	0.086	0.070	0.067	0.058	0.042	-0.084	-0.096	-0.125	-0.219
7	$A_0V_{(2)}$	$A_{(2)}V_1$	A_0V_1	$A_1V_{(2)}$	A_1V_0	A_1V_1	$A_{(2)}V_{(2)}$	$A_{(2)}V_0$	A_0V_0
	0.409	-0.523	-0.534	-0.657	-0.671	-0.702	-0.801	-0.826	-1.236
8	A_2V_1	A_0V_0	A_1V_1	A_2V_2	A_2V_0	A_1V_0	A_0V_1	A_1V_2	A_0V_2
	0.749	0.364	0.310	0.242	-0.032	-0.289	-0.663	-1.059	-3.134
9	A_1V_2	A_0V_0	A_2V_2	A_0V_1	A_1V_1	A_1V_0	A_2V_1	A_0V_2	A_2V_0
	0.354	0.299	0.028	0.027	0.018	-0.043	-0.141	-0.375	-0.463
10	A_0V_1	A_1V_2	A_2V_1	A_2V_2	A_0V_2	A_1V_0	A_2V_0	A_1V_1	A_0V_0
	-0.878	-1.018	-1.288	-1.387	-1.666	-1.668	-1.885	-1.922	-2.480

APPENDIX D

Entry of Test Cars into the Deceleration Lane

ENTRY OF TEST CARS INTO THE DECELERATION
LANE BETWEEN STATIONS

TEST CONDITION: A_0V_0



Position Of Right Front Wheel					
%In Through Lane	100.00	93.75	87.50	68.75	68.75
%Entering Deceleration lane between station	0	6.25	6.25	18.75	0
Cumulative %Entering Deceleration Lane	0	6.25	12.50	31.25	31.25
Position Of Left Front Wheel					
%In Through Lane	100.00	100.00	93.75	87.50	68.75
%Entering Deceleration lane between station	0	0	6.25	6.25	18.75
Cumulative %Entering Deceleration Lane	0	0	6.25	12.50	31.25

Figure D-1. Entry of Test Cars into the Deceleration Lane Participating in Control Group, A_0V_0.

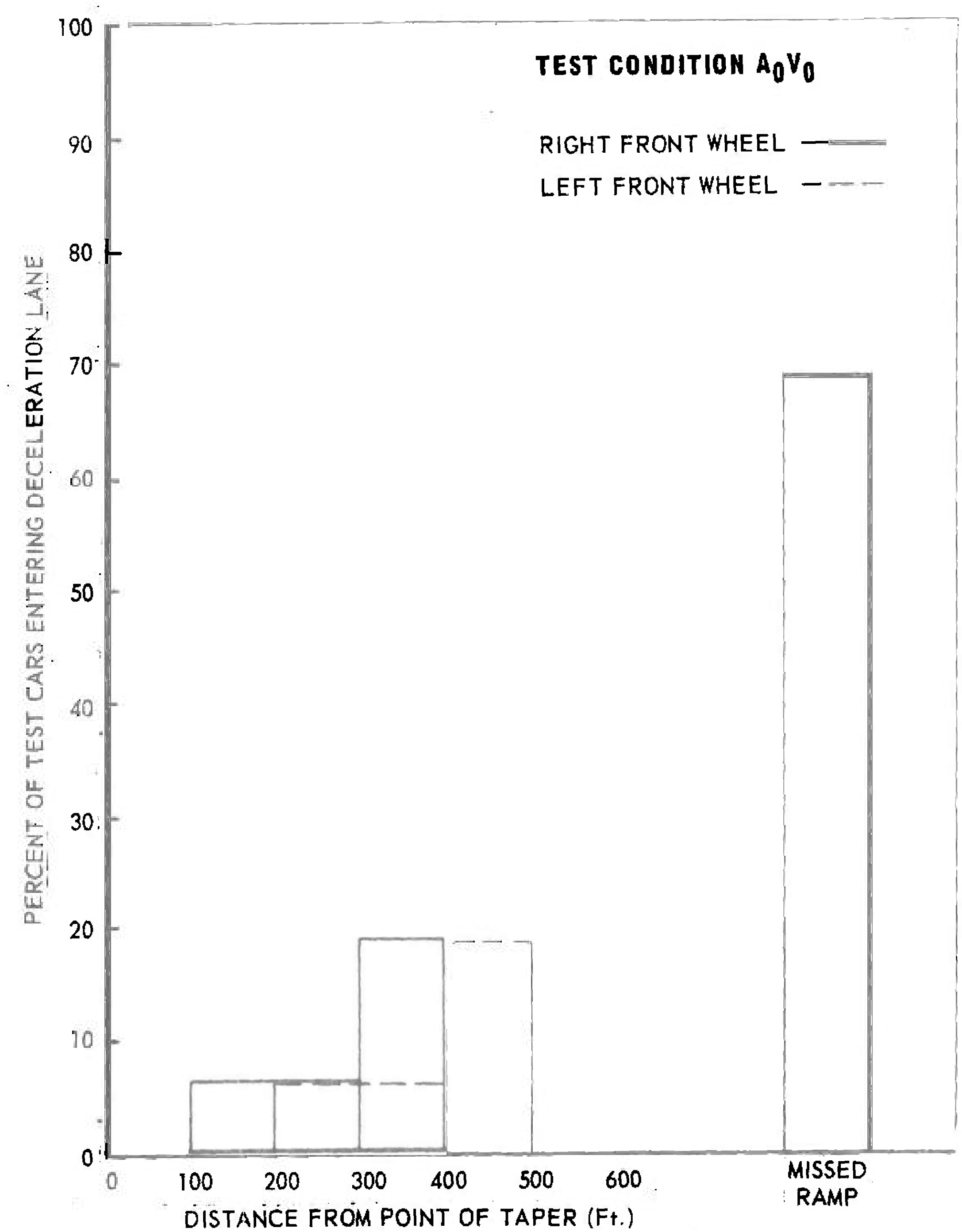
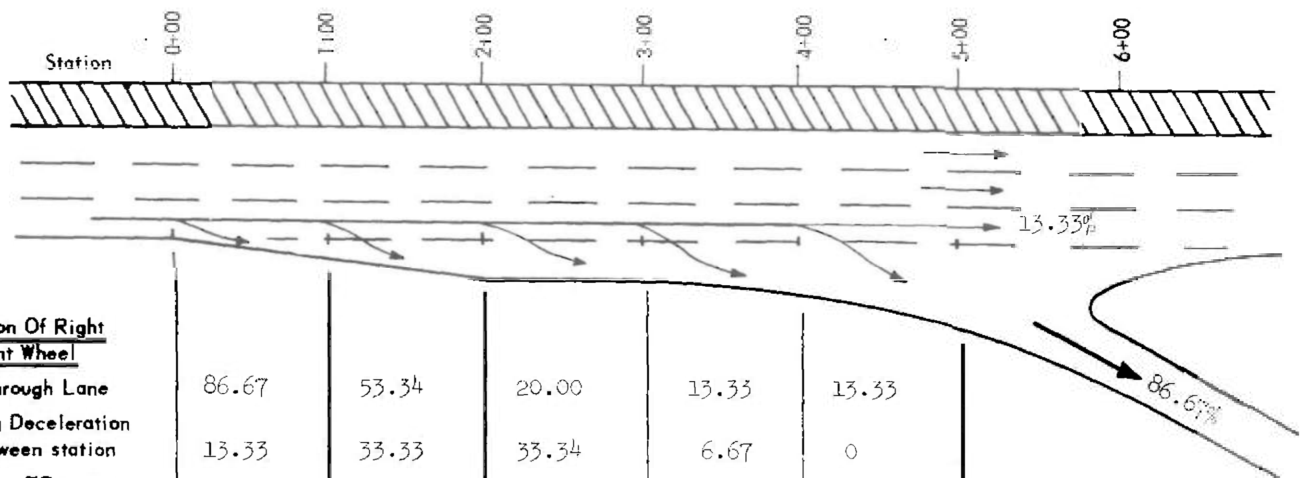


Figure D-2. Percent Entry of Test Cars into the Deceleration Lane at Various Increments, for the Control Group (A_0V_0).

ENTRY OF TEST CARS INTO THE DECELERATION LANE BETWEEN STATIONS

TEST CONDITION: A_0V_1



	0+00 to 1+00	1+00 to 2+00	2+00 to 3+00	3+00 to 4+00	4+00 to 5+00
Position Of Right Front Wheel					
%In Through Lane	86.67	53.34	20.00	13.33	13.33
%Entering Deceleration lane between station	13.33	33.33	33.34	6.67	0
Cumulative %Entering Deceleration Lane	13.33	46.66	80.00	86.67	86.67
Position Of Left Front Wheel					
%In Through Lane	100.00	86.67	73.33	33.33	13.33
%Entering Deceleration lane between station	0	13.33	13.34	40.00	20.00
Cumulative %Entering Deceleration Lane	0	13.33	26.67	66.67	86.67

Figure D-3. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Visual Advance and No Audio Information (A_0V_1).

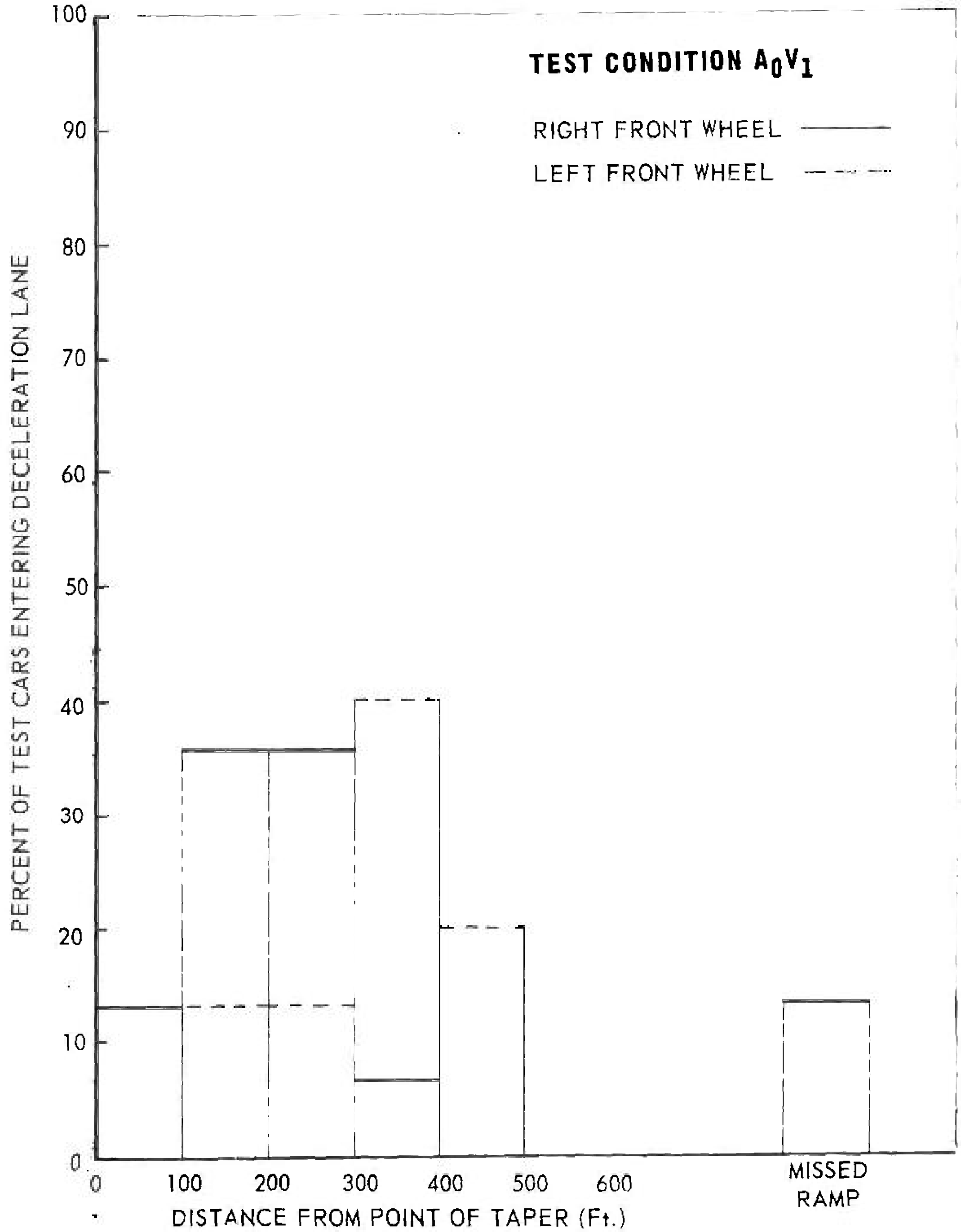
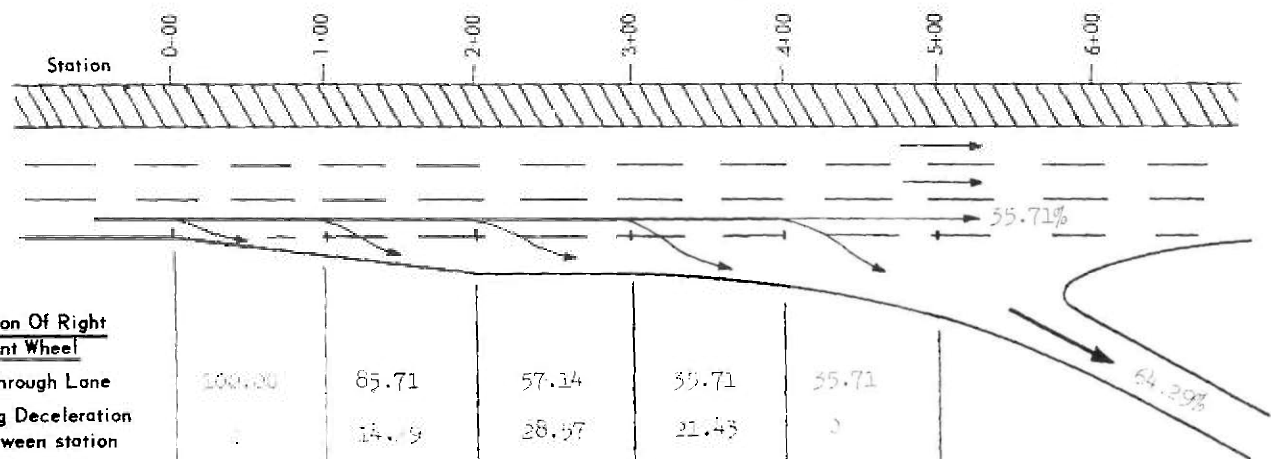


Figure D-4. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Visual Advance and No Audio Information (A_0V_1).

ENTRY OF TEST CARS INTO THE DECELERATION
LANE BETWEEN STATIONS

TEST CONDITION: A_1V_0



Position Of Right Front Wheel					
%In Through Lane	100.00	85.71	57.14	35.71	35.71
%Entering Deceleration lane between station	[illegible]	14.29	28.57	21.43	0
Cumulative %Entering Deceleration Lane	[illegible]	14.29	42.86	64.29	[illegible]
Position Of Left Front Wheel					
%In Through Lane	100.00	100.00	92.85	64.28	[illegible]
%Entering Deceleration lane between station	[illegible]	0	7.15	28.57	28.57
Cumulative %Entering Deceleration Lane	[illegible]	[illegible]	7.15	[illegible]	[illegible]

Figure D-5. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Audio Advance and No Visual Information (A_1V_0).

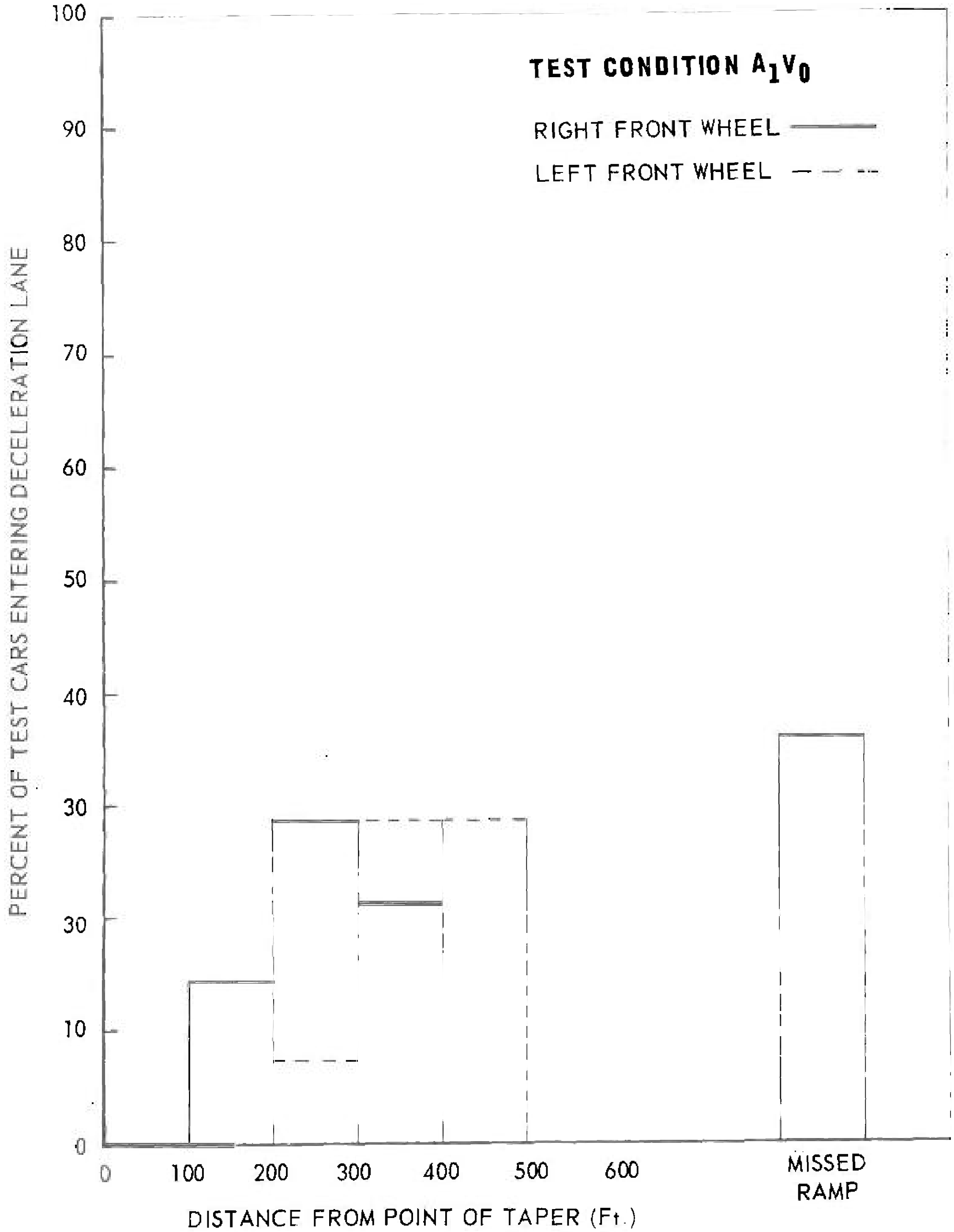
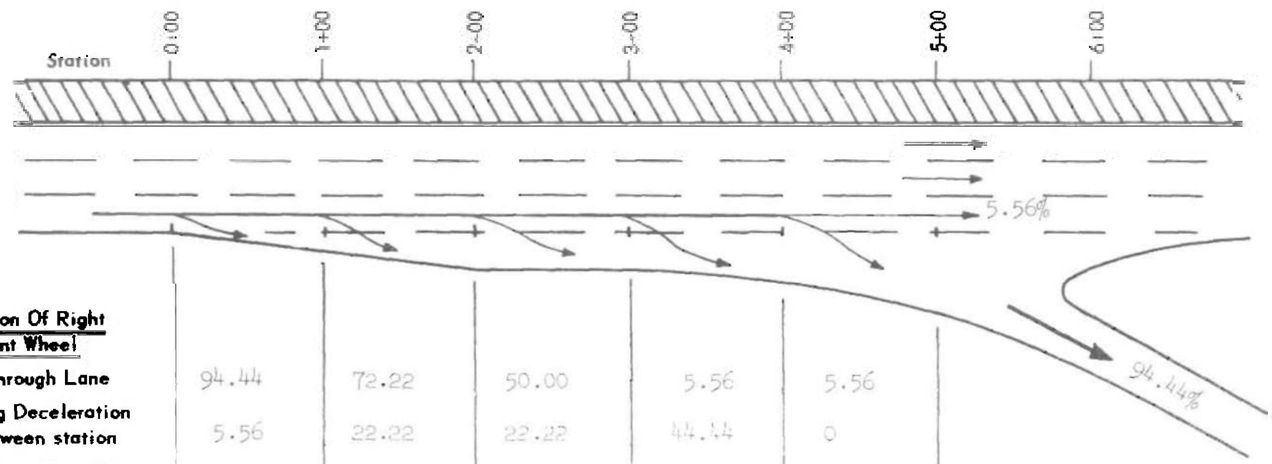


Figure D-6. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Audio Advance and No Visual Information (A_1V_0).

ENTRY OF TEST CARS INTO THE DECELERATION LANE BETWEEN STATIONS

TEST CONDITION: A_1V_1



Position Of Right Front Wheel					
%In Through Lane	94.44	72.22	50.00	5.56	5.56
%Entering Deceleration lane between station	5.56	22.22	22.22	44.44	0
Cumulative %Entering Deceleration Lane	5.56	27.78	50.00	94.44	94.44
Position Of Left Front Wheel					
%In Through Lane	100.00	100.00	66.67	27.78	5.56
%Entering Deceleration lane between station	0	0	33.33	38.89	22.22
Cumulative %Entering Deceleration Lane	0	0	33.33	72.22	94.44

Figure D-7. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Both Audio and Visual Advance Information (A_1V_1).

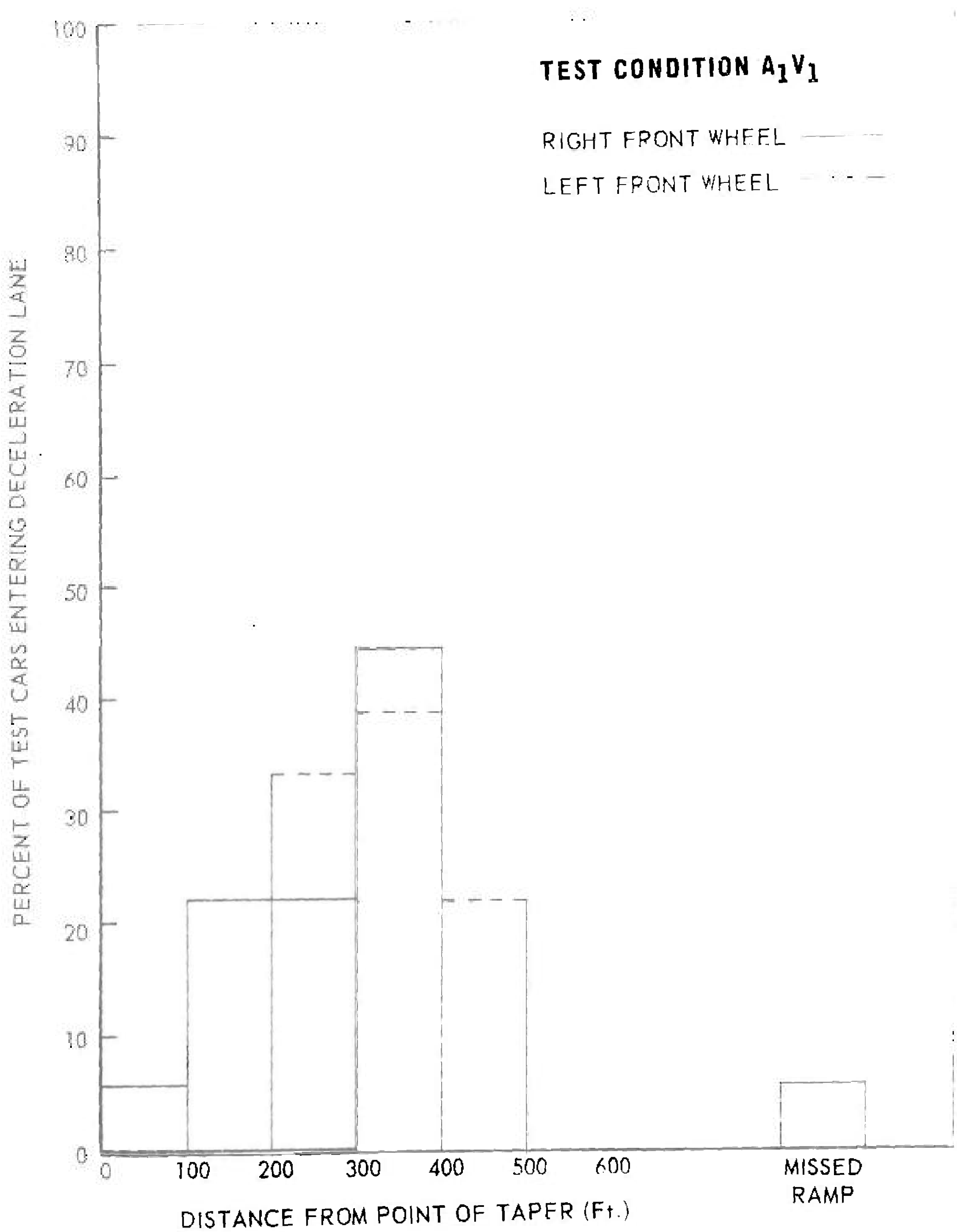
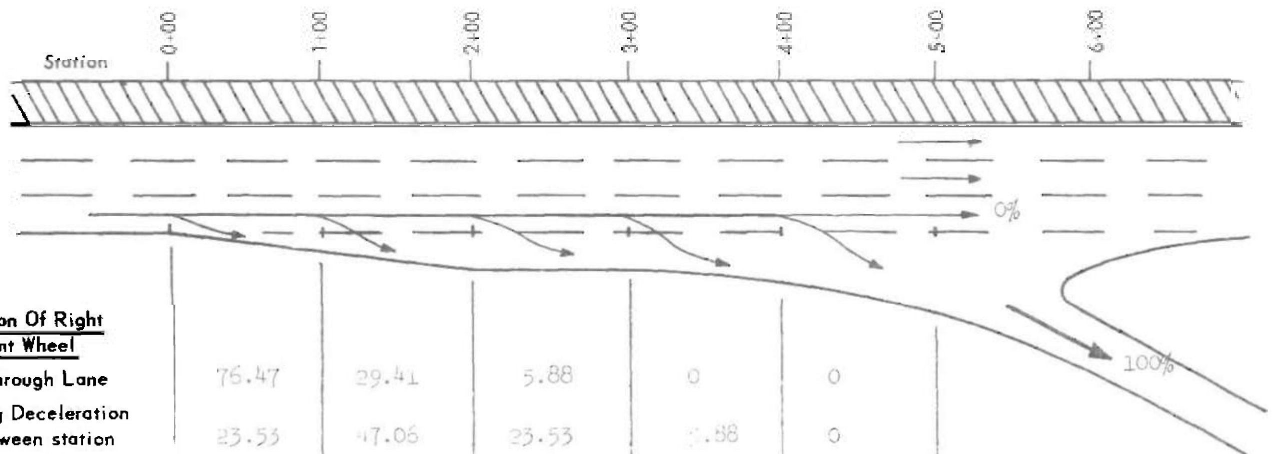


Figure B-8. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Both Audio and Visual Advance Information (A_1V_1).

ENTRY OF TEST CARS INTO THE DECELERATION
LANE BETWEEN STATIONS

TEST CONDITION: A_0V_2



Position Of Right Front Wheel					
%In Through Lane	76.47	29.41	5.88	0	0
%Entering Deceleration lane between station	23.53	47.06	23.53	5.88	0
Cumulative %Entering Deceleration Lane	23.53	70.59	94.12	100.00	100.00
Position Of Left Front Wheel					
%In Through Lane	100.00	94.12	52.94	11.76	0
%Entering Deceleration lane between station	0	5.88	41.18	41.18	11.76
Cumulative %Entering Deceleration Lane	0	5.88	47.06	88.24	100.00

Figure D-9. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Visual Advance and Exit Information, and No Audio Information (A_0V_2).

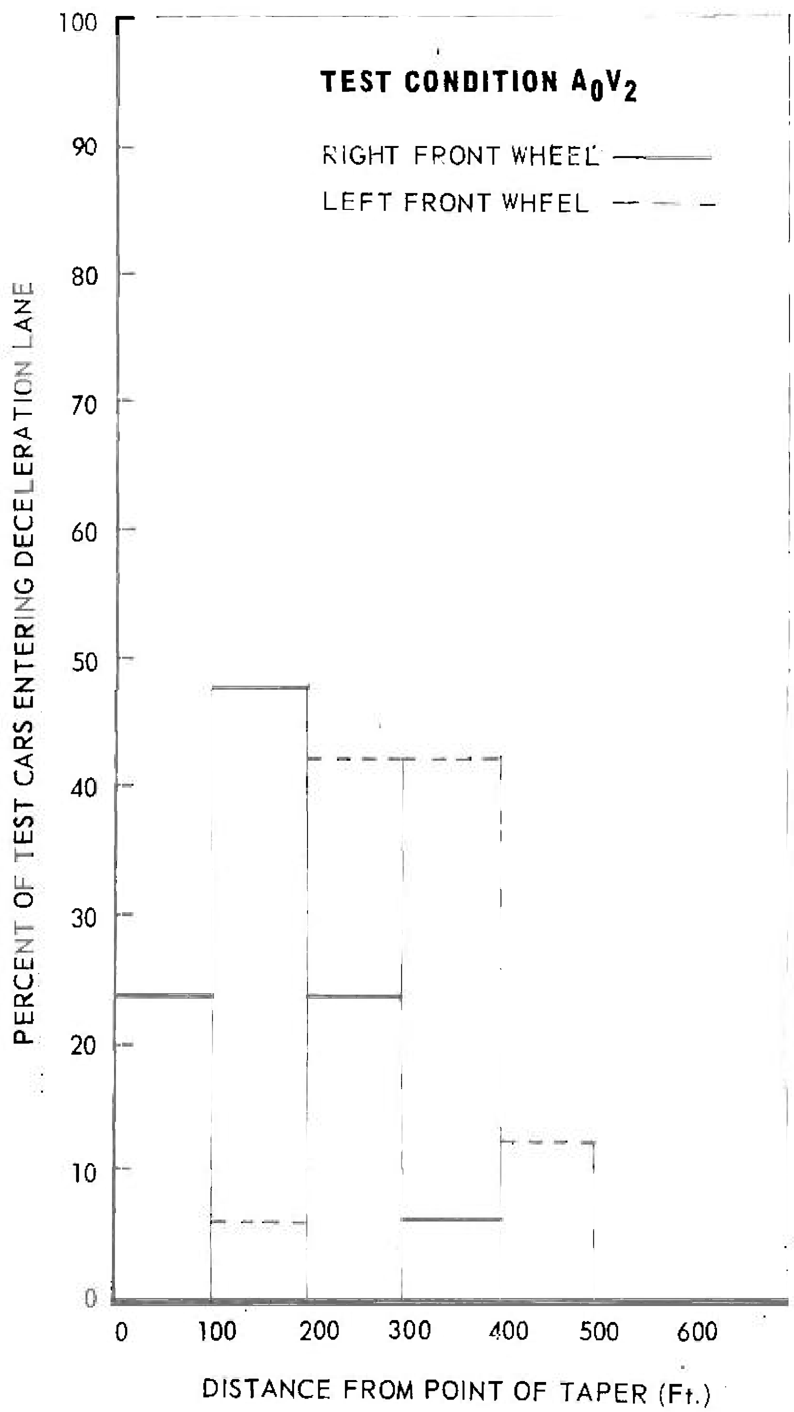
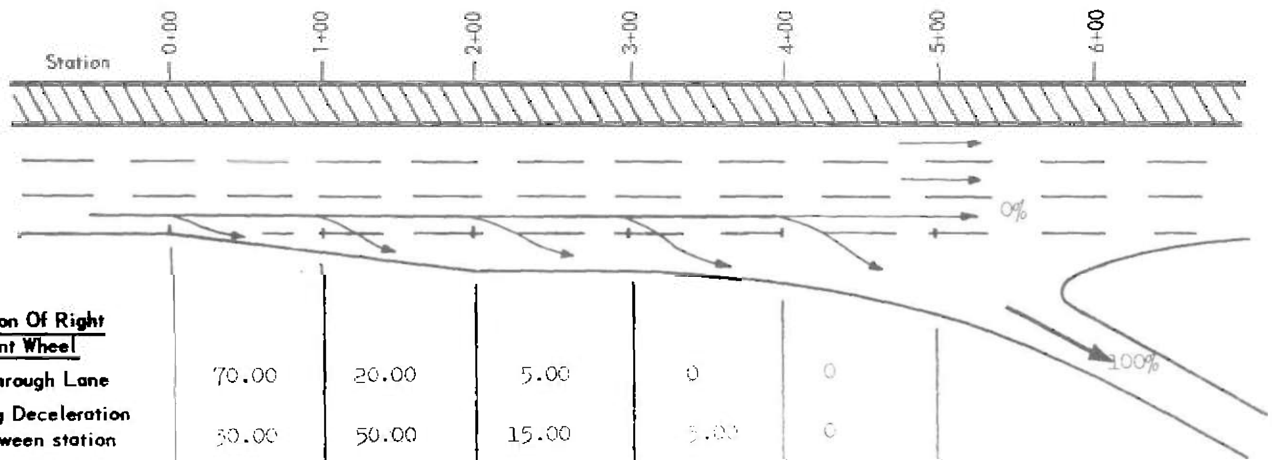


Figure D-10. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Visual Advance and Exit, and No Audio Information (A_0V_2).

ENTRY OF TEST CARS INTO THE DECELERATION LANE BETWEEN STATIONS

TEST CONDITION: A_2V_0



Position Of Right Front Wheel						
%In Through Lane	70.00	20.00	5.00	0	0	
%Entering Deceleration lane between station	30.00	50.00	15.00	5.00	0	
Cumulative %Entering Deceleration Lane	30.00	80.00	95.00	100.00	100.00	
Position Of Left Front Wheel						
%In Through Lane	100.00	85.00	40.00	10.00	0	
%Entering Deceleration lane between station	0	15.00	45.00	30.00	10.00	
Cumulative %Entering Deceleration Lane	0	15.00	60.00	90.00	100.00	

Figure D-11. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Audio Advance and Exit Information, and No Visual Information (A_2V_0).

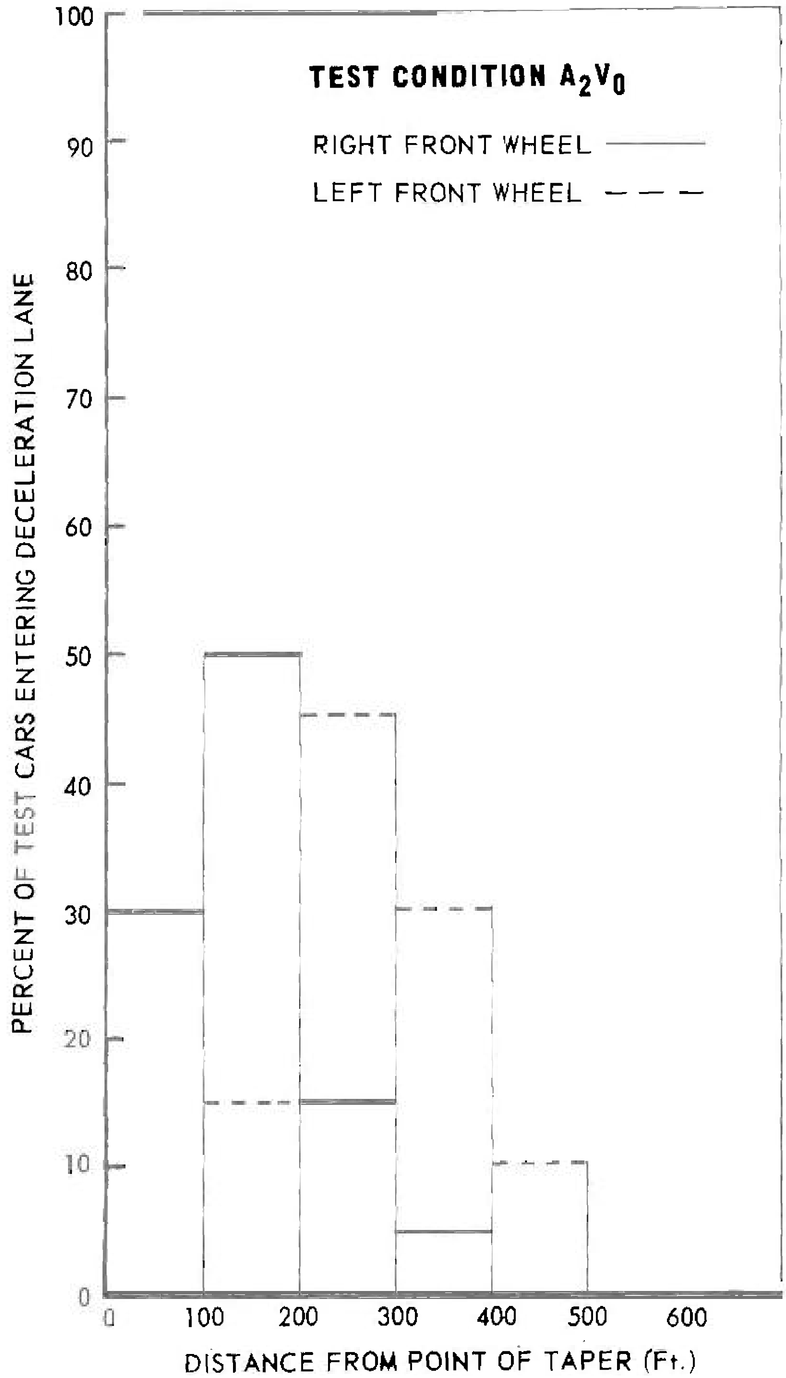
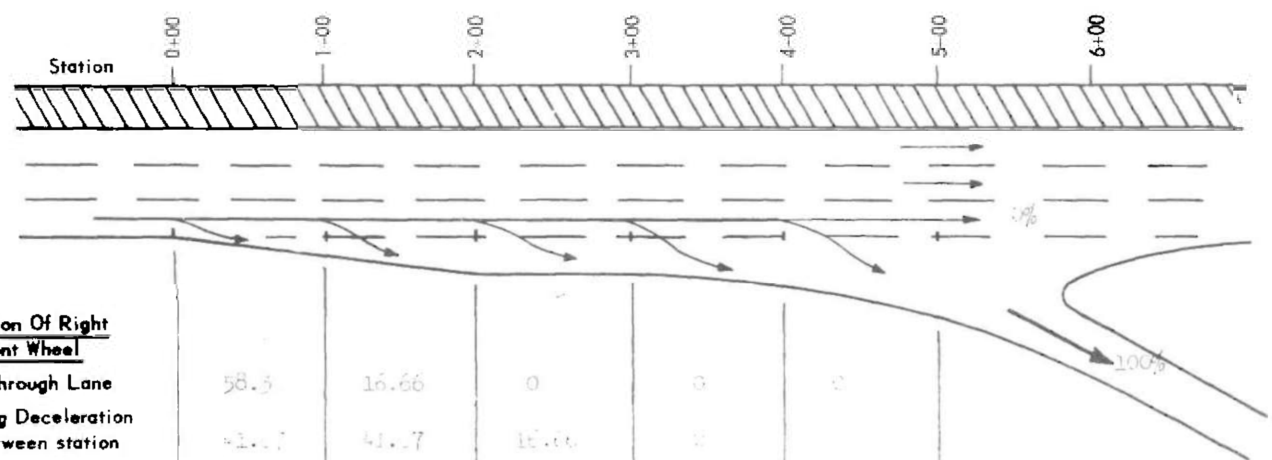


Figure D-12. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Audio Advance and Exit and No Visual Information (A_2V_0).

ENTRY OF TEST CARS INTO THE DECELERATION
LANE BETWEEN STATIONS

TEST CONDITION: A_1V_2



	0+00 to 1+00	1+00 to 2+00	2+00 to 3+00	3+00 to 4+00	4+00 to 5+00
Position Of Right Front Wheel					
%In Through Lane	58.5	16.66	0	0	0
%Entering Deceleration lane between station	[illegible]	41.7	16.66	0	
Cumulative %Entering Deceleration Lane	[illegible]	83.34	[illegible]	[illegible]	[illegible]
Position Of Left Front Wheel					
%In Through Lane	[illegible]	[illegible]	[illegible]	0	[illegible]
%Entering Deceleration lane between station	[illegible]	16.67	[illegible]	[illegible]	0
Cumulative %Entering Deceleration Lane	[illegible]	[illegible]	75.00	[illegible]	100.00

Figure D-13. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Audio Advance and Visual Advance and Exit Information (A_1V_2).

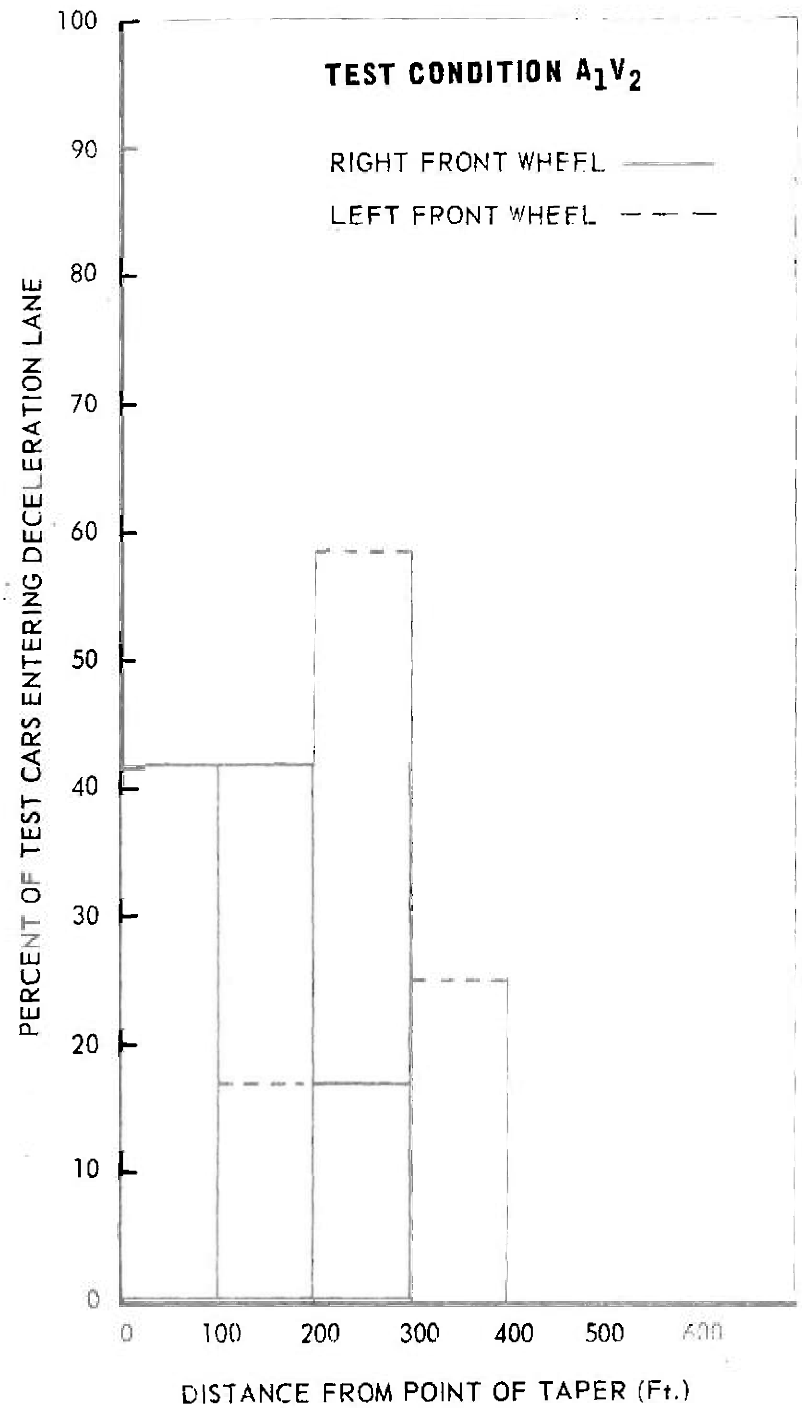
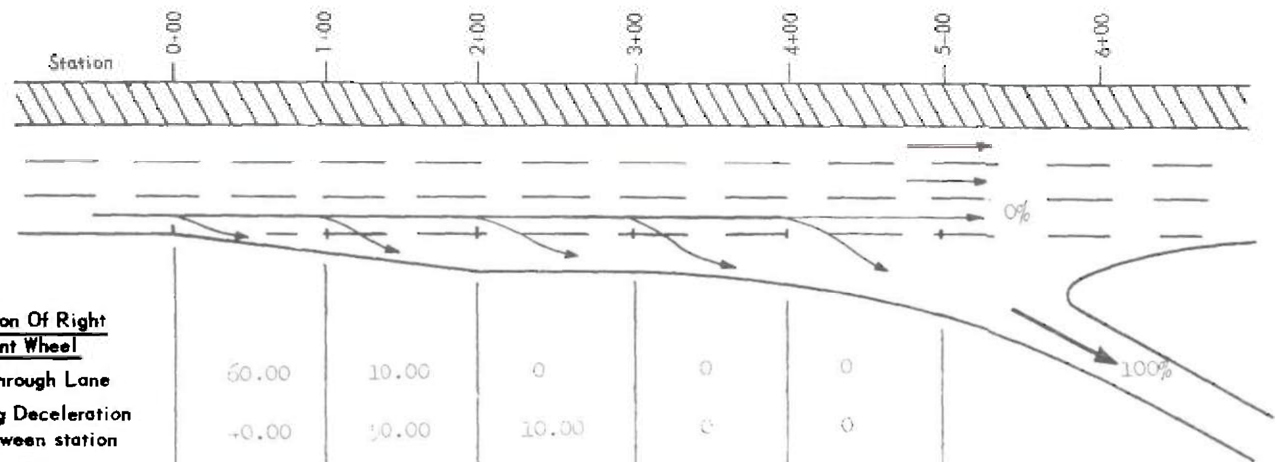


Figure D-14. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Audio Advance, and Visual Advance and Exit Information (A_1V_2).

ENTRY OF TEST CARS INTO THE DECELERATION
LANE BETWEEN STATIONS

TEST CONDITION: A_2V_1



Position Of Right Front Wheel					
%In Through Lane	60.00	10.00	0	0	0
%Entering Deceleration lane between station	40.00	50.00	10.00	0	0
Cumulative %Entering Deceleration Lane	40.00	90.00	100.00	100.00	100.00
Position Of Left Front Wheel					
%In Through Lane	100.00	95.00	20.00	0	0
%Entering Deceleration lane between station	0	5.00	75.00	20.00	0
Cumulative %Entering Deceleration Lane	0	5.00	80.00	100.00	100.00

Figure D-15. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Audio Advance and Exit, and Visual Advance Information (A_2V_1).

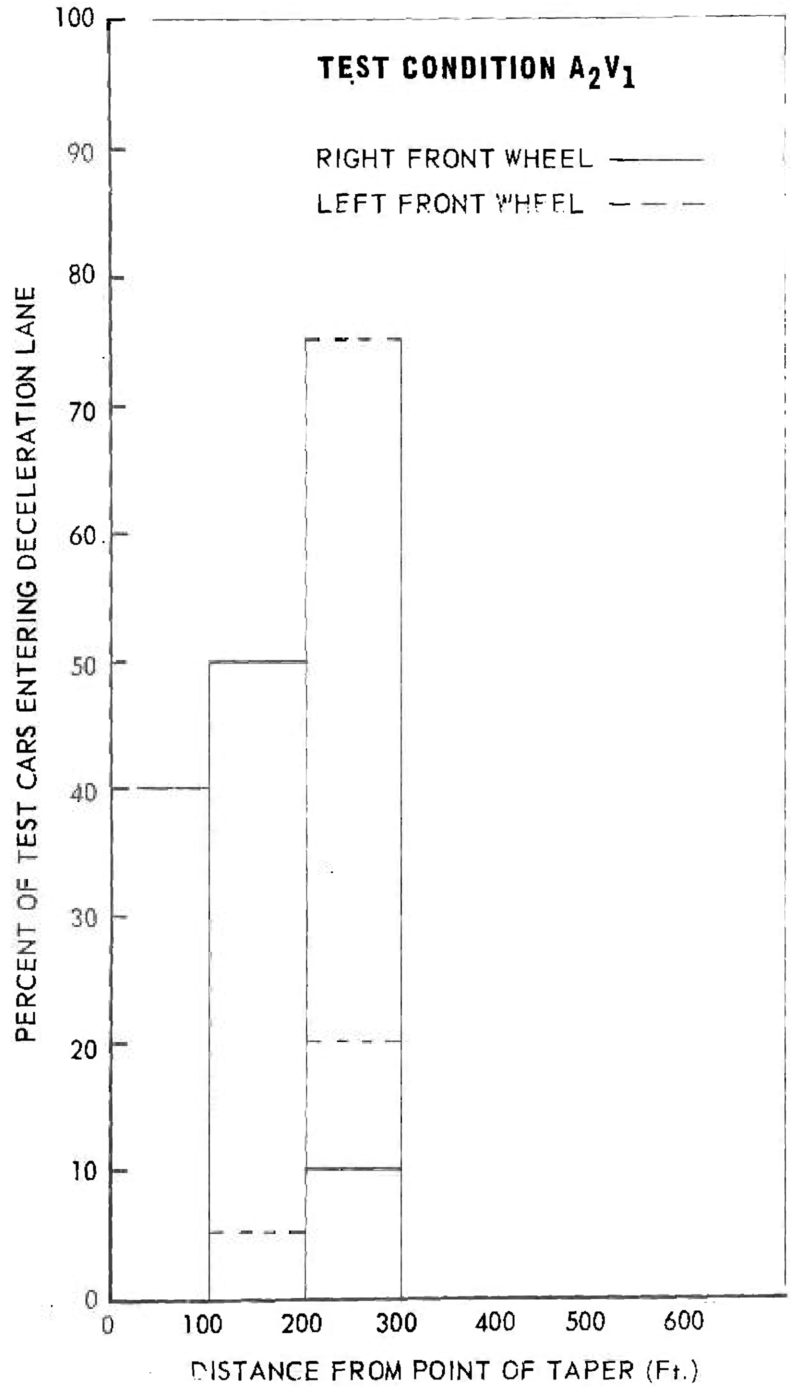
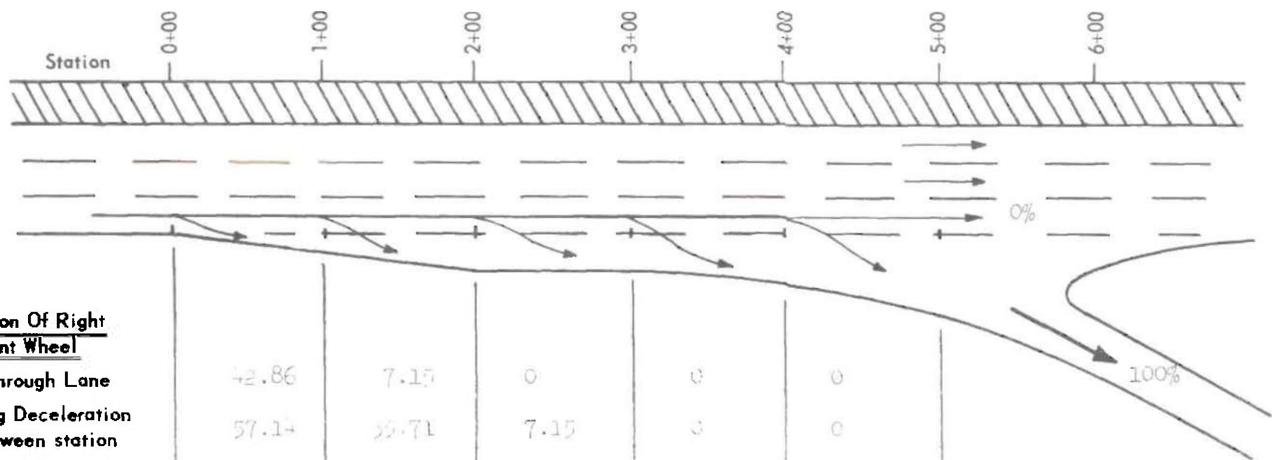


Figure D-16. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Audio Advance and Exit, and Visual Advance Information (A_2V_1).

ENTRY OF TEST CARS INTO THE DECELERATION
LANE BETWEEN STATIONS

TEST CONDITION: A_2V_2



	0+00 to 1+00	1+00 to 2+00	2+00 to 3+00	3+00 to 4+00	4+00 to 5+00
Position Of Right Front Wheel					
%In Through Lane	42.86	7.15	0	0	0
%Entering Deceleration lane between station	57.14	35.71	7.15	0	0
Cumulative %Entering Deceleration Lane	57.14	92.85	100.00	100.00	100.00
Position Of Left Front Wheel					
%In Through Lane	100.00	71.43	21.43	0	0
%Entering Deceleration lane between station	0	28.57	50.00	21.43	0
Cumulative %Entering Deceleration Lane	0	28.57	78.57	100.00	100.00

Figure D-17. Entry of Test Cars into the Deceleration Lane Participating in Test Condition with Audio Advance and Exit, and Visual Advance and Exit Information (A_2V_2).

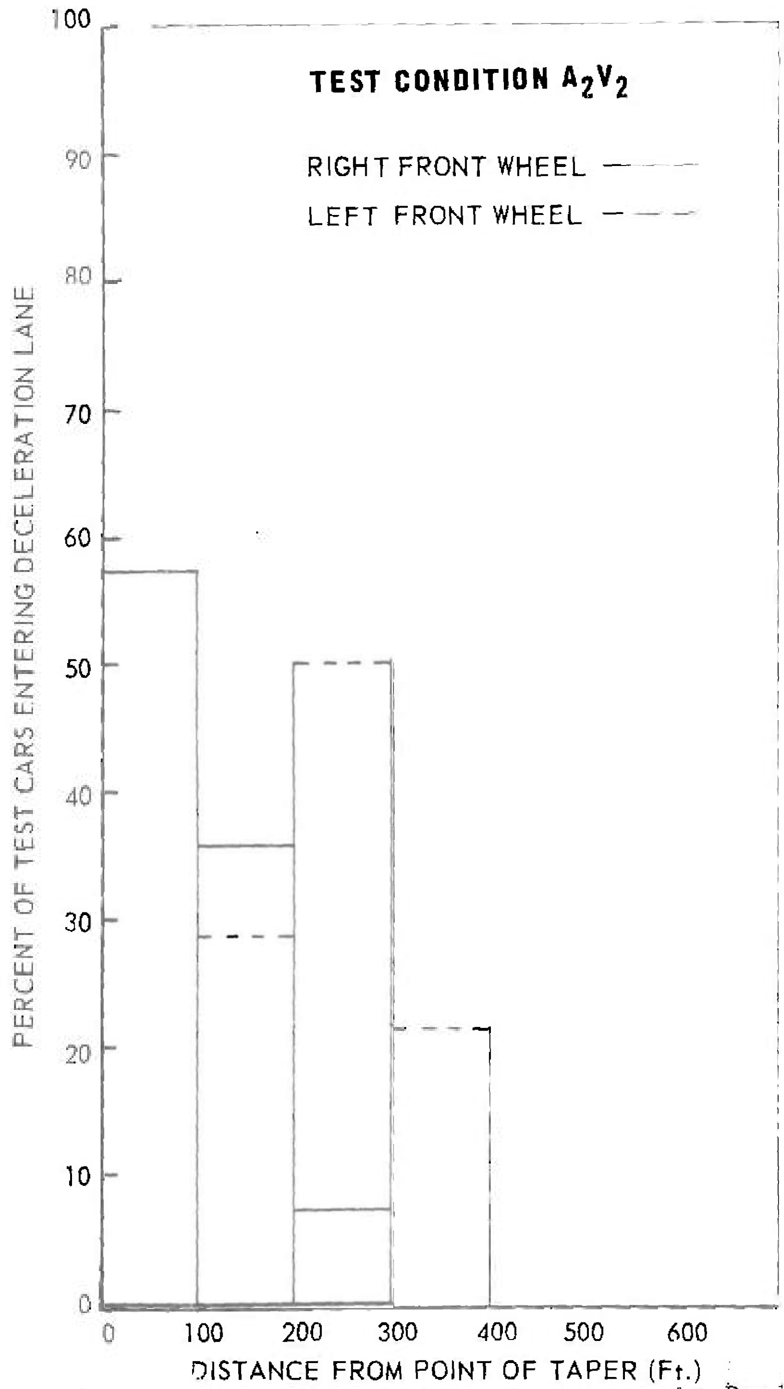


Figure D-18. Per cent Entry of Test Cars into the Deceleration Lane at Various Increments, for Test Condition with Audio Advance and Exit, and Visual Advance and Exit Information (A_2V_2).

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